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[*Frontispiece, Vol. xxxiii.*]

MAURICE DEACON,

PRESIDENT OF THE INSTITUTION OF MINING ENGINEERS, 1906-1907.

TRANSACTIONS

OF

THE INSTITUTION

OF

MINING ENGINEERS.

VOL. XXXIII.—1906-1907.

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CONTENTS OF VOL. XXXIII.

PAGE.

ADVERTIZEMENT ii
CONTENTS iii
OFFICERS x
BYE-LAWS xii
SUBJECTS FOR PAPERS xviii

GENERAL MEETINGS.

THE INSTITUTION OF MINING ENGINEERS.

1907. PAGE.

June 13.—General Meeting (London) 329
Prizes 329
"Presidential Address." By M. Deacon 330
Discussion 345
"Improvements required in Inland Navigation." By Henry Rodolph de Salis 347
Discussion 363
"A Bye-product Coking-plant at Clay Cross." By W. B. M. Jackson 386
"Notes on Bye-product Coke-ovens, with Special Reference to the Koppers Oven." By A. Victor Kochs 398
Discussion 416
"The Application of Duplicate Fans to Mines." By the Rev. G. M. Capell 431
Discussion 433
Discussion of Mr. Sam Mavor's paper on "Practical Problems of Machine-mining" 445
"Gypsum in Sussex." By W. J. Kemp and G. Alfred Lewis ... 449
Discussion 468
"Water-supplies by Means of Artesian Bored Tube-wells." By Herbert F. Broadhurst 473
Discussion 497
June 14.—General Meeting (London) 501
Discussion of Mr. A. Thompson's paper on "Electrically-driven Air-compressors combined with the working of Ingersoll-Sergeant Heading-machines," etc. 501
"The Thick Coal of Warwickshire." By J. T. Browne 502
Discussion 513
"New Rand Gold-field, Orange River Colony." By A. R. Sawyer 530
Discussion 531
"The Ozokerite (Mineral-wax) Mine of the Galizische Kreditbank, at Boryslaw, Galicia, Austria." By D. M. Chambers ... 535
"Notes on the Structural Geology of South Africa." By C. Sandberg 540
Discussion 556
"A Single-room System of Mining: An Adaptation of the Long-wall Method to Work in Thick Seams." By H. S. Gay ... 558

THE INSTITUTION OF MINING ENGINEERS.—*Continued.*

1907. PAGE.

June 14.—General Meeting (London).—*Continued.*

"Cast-iron Tubbing: What is its Rational Formula?" By H. W. G. Halbaum 567

Discussion 617

Visits to Works, etc.:—

Park Royal Power-station of the Great Western Railway Company 634

The Knight, Bevan & Sturge Works of the Associated Portland Cement Manufacturers (1900), Limited, Northfleet, Kent 642

"Electric Transmission of Power at the Works and Collieries of the Grand-Hornu, Belgium." By E. Troussart 647

"Hauling Arrangement at the Face" 663

Florence Coal and Iron Company, Limited 664

Discussion of Mr. H. W. G. Halbaum's paper on "Cast-iron Tubbing: What is its Rational Formula?" 664

"Memoir of Sir Lowthian Bell, Bart." 665

MANCHESTER GEOLOGICAL AND MINING SOCIETY.

1907.

Feb. 12.—General Meeting (Manchester) 170

Discussion of Mr. Otto Simonis' paper on "Liquid Air and its Use in Rescue-apparatus" 170

"Cage-lowering Tables at New Moss Colliery." By T. H. Wordsworth 174

Discussion 177

March 12.—General Meeting (Manchester) 277

Discussion of Mr. W. E. Garforth's paper on "A New Apparatus for Rescue-work in Mines" 277

April 9.—General Meeting (Manchester) 282

"The Cook Calorimetric Bomb." By W. H. Coleman 283

Discussion 288

May 14.—General Meeting (Manchester) 290

"The Rock-salt Deposits at Preesall, Fleetwood, and the Mining Operations Therein." By Fredk. J. Thompson ... 291

Discussion 298

THE MIDLAND COUNTIES INSTITUTION OF ENGINEERS AND THE MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

1907.

March 9.—Joint General Meeting (Chesterfield) 120

Discussion of Mr. I. Hodges' paper on "An Account of Sinking and Tubbing at Methley Junction Colliery, with a Description of a Cast-iron Dam to resist an Outburst of Water" ... 120

Discussion of Messrs. W. N. Atkinson and A. M. Henshaw's paper on "The Courrières Explosion" 124

"Elliott Washer and Hardy Dust-extractor and Grinder." By E. Greaves 138

Discussion 149

THE MIDLAND COUNTIES INSTITUTION OF ENGINEERS AND THE MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.—*Continued.*

1907. PAGE.
March 9.—Joint General Meeting (Chesterfield).—*Continued.*
Discussion of Mr. W. C. Mountain's paper on the "Commercial Possibilities of Electric Winding for Main Shafts and Auxiliary Work" 150

MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

1907.
Feb. 20.—General Meeting (Barnsley) 89
"The Importance of Scientific Mining in the Barnsley District." By R. Sutcliffe 90
Discussion 99
"The Most Suitable Form of Guides for Cages for Winding from Deep Shafts: 1,500 Feet and Deeper." By N. W. Routledge 104
"The Most Suitable Form of Guides for Cages for Winding from Deep Shafts: 1,500 Feet and Deeper." By A. J. Kennedy 108
Discussion 113
March 23.—Excursion Meeting (Altofts) 205
Experimental Gallery at Altofts Collieries 205
April 9.—General Meeting (Sheffield) 208
"Report on Rescue-work done by Men wearing Rescue-apparatus in the Experimental Gallery at Messrs. Pope and Pearson's Collieries, Altofts, on March 23rd, 1907" 209
"The Use and Care of Oxygen-breathing Apparatus." By M. H. Habershon 212
Discussion 222

THE MINING INSTITUTE OF SCOTLAND.

1907.
Feb. 13.—General Meeting (Glasgow) 52
Discussion of Mr. George Ness' paper on "Effects of Acceleration on Winding-torques, and Test of Tarbrax Electrical Winding-plant" 52
Discussion of Mr. John B. Thomson's paper on "Tests of a Mine-fan" 58
"Heading by Longwall Machines." By Sam Mavor 65
April 11.—Annual General Meeting (Hamilton) 151
Annual Report of the Council, 1906-1907 151
Election of Officers, 1907-1908 153
Accounts 154
Discussion of Mr. John B. Thomson's paper on "Tests of a Mine-fan" 155
Discussion of Mr. Sam Mavor's paper on "Heading by Longwall Machines" 157
"A Stretcher for Use in Mines." By John F. K. Brown ... 162
"The Hanley Cage Guardian." By Albert Hanley 164
June 29.—Excursion Meeting (Polmaise Collieries) 235
June 29.—General Meeting (Stirling) 236
"Polmaise Collieries." By James Salmond 237

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

1907.	PAGE.
Feb. 9.—General Meeting (Newcastle-upon-Tyne)	1
Discussion of Mr. Otto Simonis' paper on "Liquid Air and its Use in Rescue-apparatus"	2
"Ferro-concrete and its Applications." By T. J. Gueritte ...	10
April 13.—General Meeting (Newcastle-upon-Tyne)	179
Discussion of Mr. W. E. Garforth's paper on "A New Apparatus for Rescue-work in Mines"	180
Discussion on the Explosion at Wingate Grange Colliery ..	183
Discussion of Mr. E. Seymour Wood's paper on "Sinking through Magnesian Limestone and Yellow Sand by the Freezing-process at Dawdon Colliery, near Seaham Harbour, County Durham"	197
"Sliding-trough Conveyors." By M. Malplat	198
Discussion	200
"Memoir of the late John Daglish." By M. Walton Brown ...	201
June 8.—General Meeting (Newcastle-upon-Tyne)	249
Discussion of Mr. R. Cremer's paper on "The Pneumatogen: The Self-generating Rescue-apparatus, compared with Other Types"	250
Discussion of Mr. E. S. Wood's paper on "Sinking through Magnesian Limestone and Yellow Sand by the Freezing-process at Dawdon Colliery, near Seaham Harbour, County Durham"	251
"Treatment of Dust in Mines, Aboveground and Belowground." By Richard Harle	254
Discussion	257
June 6.—Excursion Meeting (Sunderland)	275
C Pit, Monkwearmouth	275

THE NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

1907.	
Feb. 4.—General Meeting (Stoke-upon-Trent)	76
Death of Mr. W. H. Davies	76
Prizes	77
"A Gob-fire in a Shropshire Mine." By St. V. Champion Jones	78
Discussion	84
April 8.—General Meeting (Stoke-upon-Trent)	303
Discussion of Messrs. W. N. Atkinson and A. M. Henshaw's paper on "The Courrières Explosion"	303
June 3.—General Meeting (Stoke-upon-Trent)	312
"Outbursts of Coal and Gas in the Cockshead Seam, Shelton Colliery." By F. E. Buckley	313
Discussion	320
Discussion of Messrs. W. N. Atkinson and A. M. Henshaw's paper on "The Courrières Explosion"	326
June 24.—Excursion Meeting (Tutbury)	328
Tutbury Gypsum-mines and Plaster-mills	328

THE SOUTH STAFFORDSHIRE AND WARWICKSHIRE INSTITUTE OF MINING ENGINEERS.

1907. PAGE.
Feb. 12.—General Meeting (Birmingham) 25
"The Hidden Coal-fields of the Midlands." By Charles Lapworth 26
Discussion 50
April 16.—General Meeting (Birmingham) 167
Discussion of Mr. F. C. Swallow's paper on "Boilers for Colliery Purposes" 167
Discussion of Mr. A. Hanley's paper on "The Hanley Cage Guardian" 168
June 4.—General Meeting (Birmingham) 261
Discussion of Prof. C. Lapworth's paper on "The Hidden Coal-fields of the Midlands" 261

APPENDICES.

I.—Notes of Papers on the Working of Mines, Metallurgy, etc., from the Transactions of Colonial and Foreign Societies and Colonial and Foreign Publications 673
"Brown-coal Deposits of Upper Lausitz, Silesia." By Kurt Priemel 673
"*Posidonia Becheri* in Upper Silesian Coal-measures." By R. Michael 675
"Asphalt-deposit at Mettenheim, Hesse." By A. Steuer ... 675
"Kaolin-deposits of Halle-an-der-Saale, Saxony." By Ewald Wüst 676
"Nickeliferous Magnetic Pyrites of the Black Forest, Baden." By E. Weinschenk 677
"Stanniferous Deposits of the Fichtelgebirge, Bavaria." By Albert Schmidt 679
"Holzappel Metalliferous Belt, Hesse-Nassau." By G. Einecke 680
"Pyrites-deposits of the Western Erzgebirge, Saxony." By Otto Mann 680
"Tungsten-ore Deposits in Saxony." By R. Beck 682
"Graphite-deposits in the Piedmontese Alps." By Vittorio Novarese 683
"Azurite-deposit of the Castello di Bonvei, Sardinia." By F. Millosevich 685
"Tungsten-ores in the Cagliari District, Sardinia." By Domenico Lovisato... 686
"Metalliferous Deposits of North-eastern Sicily." By B. Lotti 687
"Blende- and Galena-deposits of Traag, Norway." By J. H. L. Vogt 689
"Gellivaara and Kiirunavaara Iron-ores, Northern Sweden":—
(1) By O. Stutzer 690
(2) By O. Stutzer 692
(3) By O. Stutzer 692
"Graphite-deposits in Lapland." By O. Stutzer 693

APPENDICES.—*Continued.*

I.—Notes of Papers, etc.—*Continued.* PAGE.

"Auriferous Deposits of Finnish Lapland." By Curt Fircks ... 693

"Manganiferous and Other Ore-deposits of Nizhne-Tagilsk, Russia":—

(1) By N. Yakovlev 695

(2) By A. Krasnopolsky 695

"Auriferous Deposits of Servia." By Douchan Jovanovitch ... 695

"Mercury Ore-deposits of Avala Hill, Servia." By H. Fischer 697

"Ore-deposits of the Province of Almeria, Spain":—

(1) By O. Pütz 699

(2) By Baron F. Fircks 701

(3) By Baron F. Fircks 702

"Huelva Pyrites-deposits, Spain." By Bruno Wetzig 704

"Argentiferous Galena of Cadlimo, Switzerland." By E. Mariani 707

"Mineral-resources of Asia Minor":—

(1) By Fr. Freise 708

(2) By C. Schmeisser 709

"Coal-bearing Beds of Fushun, Southern Manchuria." By J. Palibin 712

"Mineral Resources of Korea." By — Berteaux 712

"Coal-bearing Beds in the Kuznetsk District, Siberia." By B. K. Polienov 713

"Gold-bearing Regions of Siberia":—

(1) By E. Ahnert 714

(2) By A. Gerasimoff and P. I. Preobrazhensky ... 714

(3) By E. Ahnert, M. M. Ivanoff, A. Khlaponin, P. Rippas and P. Yavorovsky 714

(4) By A. Khlaponin 714

(5) By Ernst Maier 716

"Mineral Resources of the Chukchen Peninsula, Eastern Siberia." By J. Korsuchin 719

"Copper, Tin and Gold in Katanga, Congo Free State":—

(1) By H. Buttgenbach 721

(2) By H. Buttgenbach 722

(3) By H. Buttgenbach 723

II.—Barometer, Thermometer, etc., Readings for the Year 1906. By Percy Strzelecki 725

INDEX 735

List of Plates:—

	PAGE.
Portrait of Mr. Maurice Deacon	*Frontispiece*
I.	84
II.	106
III.	112
IV.	162
V.	166
VI.	176
VII.	201
VIII.	206
IX.	256
X.	298
XI.	320
XII.	396
XIII., XIV., XV., XVI.	416
XVII.	432
XVIII.	496
XIX.	512
XX.	530
XXI.	556
XXII.	566
XXIII.	616
XXIV., XXV.	642
XXVI., XXVII.	662
XXVIII.	734
XXIX.	734

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THE INSTITUTION OF MINING ENGINEERS.

FOUNDED JULY 1ST, 1889.

BYE-LAWS.

As revised at Council Meeting held on September 13th, 1905.

I.—CONSTITUTION.

1.—The Institution of Mining Engineers shall consist of all or any of the societies interested in the advancement of mining, metallurgy, engineering and their allied industries, who shall from time to time join together and adhere to the bye-laws.

2.—The Institution shall have for its objects—

(*a*) The advancement and encouragement of the sciences of mining, metallurgy, engineering, and their allied industries.

(*b*) The interchange of opinions, by the reading of communications from members and others, and by discussions at general meetings, upon improvements in mining, metallurgy, engineering, and their allied industries.

(*c*) The publication of original communications, discussions, and other papers connected with the objects of the Institution.

(*d*) The purchase and disposal of real and personal property for such objects.

(*e*) The performance of all things connected with or leading to the purpose of such objects.

3.—The offices of the Institution shall be in Newcastle-upon-Tyne, or such other place as shall be from time to time determined by resolution of the Council.

4.—The year of the Institution shall end on July 31st in every year.

5.—The affairs and business of the Institution shall be managed and controlled by the Council.

II.—MEMBERSHIP.

6.—The original adherents or founders are as follows:—

(*a*) Chesterfield and Midland Counties Institution of Engineers, Chesterfield.

(*b*) Midland Institute of Mining, Civil and Mechanical Engineers, Barnsley.

(*c*) North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne.

(*d*) South Staffordshire and East Worcestershire Institute of Mining Engineers, Birmingham.

7.—Written applications from societies to enter the Institution shall be made to the Council, by the President of the applying society, who shall furnish any information that may be desired by the Council.

8.—A.—If desired by the Council, any of the Federated Institutes shall revise their bye-laws, in order that their members shall consist of Ordinary Members, Associate Members, and Honorary Members, with Associates and Students, and section B following shall be a model bye-law to be adopted by any society when so desired by the Council.

B.—"The members shall consist of Ordinary Members, Associate Members and Honorary Members, with Associates and Students:—

(*a*) Each Ordinary Member shall be more than twenty-three years of age, have been regularly educated as a mining, metallurgical, or mechanical engineer, or in some other branch of engineering, according to the usual routine of pupilage, and have had subsequent employment for at least two years in some responsible situation as an engineer; or if he has not undergone the usual routine of pupilage, he must have been employed or have practised as an engineer for at least five years.

(*b*) Each Associate Member shall be a person connected with or interested in mining, metallurgy, or engineering, and not practising as a mining, metallurgical, or mechanical engineer, or some other branch of engineering.

(*c*) Each Honorary Member shall be a person who has distinguished himself by his literary or scientific attainments, or who may have made important communications to any of the Federated Institutes.

(*d*) Associates shall be persons acting as under-viewers, under-managers, or in other subordinate positions in mines or metallurgical works, or employed in analogous positions in other branches of engineering.

(*e*) Students shall be persons who are qualifying themselves for the profession of mining, metallurgical, or mechanical engineering, or other branch of engineering, and such persons may continue Students until they attain the age of twenty-five years."

9.—The Ordinary Members, Associate Members and Honorary Members, Associates and Students shall have notice of, and the privilege of attending, the ordinary and annual general meetings, and shall receive all publications of the Institution. They may also have access to, and take part in, the general meetings of any of the Federated Institutes.

10.—The members of any Federated Institute, whose payments to the Institution are in arrear, shall not receive the publications and other privileges of the Institution.

11.—After explanations have been asked by the President from any Federated Institute, whose payments are in arrear, and have not been paid within one month after written application by the Secretary, the Council may decide upon its suspension or expulsion from the Institution; but such suspension or expulsion shall only be decided at a meeting attended by at least two-thirds of the members of the Council by a majority of three-fourths of the members present.

III.—Subscriptions.

12.—Each of the Federated Institutes shall pay fifteen shillings per annum for each Ordinary Member, Associate Member, Honorary Member, Associate and Student, or such other sum, and in such instalment or instalments as may be determined from time to time by resolution or resolutions of the Council. Persons joining any of the Federated Institutes during the financial year of the Institution shall be entitled to all publications issued for that year, after his election is notified to the Secretary, and the instalment or instalments due on his behalf have been paid.

IV.—Election of Officers and Council.

13.—The officers of the Institution, other than the Secretary and Treasurer, shall consist of Councillors elected annually prior to August in each year, by and out of the Ordinary Members and Associate Members of each Federated Institute, in the proportion of one Councillor per forty Ordinary Members or Associate Members thereof; of Vice-Presidents elected by and from the Council at their first meeting in each year on behalf of each Institute, in the proportion of one Vice-President per two hundred Ordinary Members or Associate Members thereof; and of a President elected by and from the Council at their first meeting in each year; who, with the Local Secretaries of each Federated Institute and the Secretary and Treasurer, shall form the Council. All Presidents on retiring from that office shall be *ex-officio* Vice-Presidents so long as they continue Ordinary Members or Associate Members of any of the Federated Institutes.

14.—In case of the decease, expulsion, or resignation of any officer or officers, the Council may, if they deem it requisite, fill up the vacant office or offices at their next meeting.

V.—Duties of Officers and Council.

15.—The Council shall represent the Institution and shall act in its name, and shall make such calls upon the Federated Institutes as they may deem necessary, and shall transact all business and examine accounts, authorise payments and may invest or use the funds in such manner as they may from time to time think fit, in accordance with the objects and bye-laws of the Institution.

16.—The Council shall decide the question of the admission of any society, and may decree the suspension or expulsion of any Federated Institute for non-payment of subscriptions.

17.—The Council shall decide upon the publication of any communications.

18.—There shall be three ordinary meetings of the Council in each year, on the same day as, but prior to, the ordinary or annual general meetings of the members.

19.—A special meeting of the Council shall be called whenever the President may think fit, or upon a requisition to the Secretary signed by ten or more of its members, or by the President of any of the Federated Institutes. The business transacted at a special meeting of the Council shall be confined to that specified in the notice convening it.

20.—The meetings of the Council shall be called by circular letter, issued to all the members at least seven days previously, accompanied by an agenda-paper, stating the nature of the business to be transacted.

21.—The order in which business shall be taken at the ordinary and annual general meetings may be, from time to time, decided by the Council.

22.—The Council may communicate with the Government in cases of contemplated or existing legislation, of a character affecting the interests of mining, metallurgy, engineering, or their allied industries.

23.—The Council may appoint Committees, consisting of members of the Institution, for the purpose of transacting any particular business, or of investigating any specific subject connected with the objects of the Institution.

24.—A Committee shall not have power or control over the funds of the Institution, beyond the amount voted for its use by the Council.

25.—Committees shall report to the Council, who shall act thereon and make use thereof as they may elect.

26.—The President shall take the chair at all meetings of the Institution, the Council, and Committees at which he may be present.

27.—In the absence of the President, it shall be the duty of the senior Vice-President present to preside at the meetings of the Institution. In case of the absence of the President and of all the Vice-Presidents, the meeting may elect any member of Council, or in case of their absence any Ordinary Member or Associate Member to take the chair at the meeting.

28.—At meetings of the Council six shall be a quorum.

29.—Every question shall be decided at the meetings of the Council by the votes of the majority of the members present. In case of equal voting, the President, or other member presiding in his absence, shall have a casting vote. Upon the request of two members, the vote upon any question shall be by ballot.

30.—The Secretary shall be appointed by and shall act under the direction and control of the Council. The duties and salary of the Secretary shall be fixed and varied from time to time at the will of the Council.

31.—The Secretary shall summon and attend all meetings of the Council, and the ordinary and annual general meetings of the Institution, and shall record the proceedings in the minute book. He shall direct the administrative and scientific publications of the Institution. He shall have charge of and conduct all correspondence relative to the business and proceedings of the Institution, and of all committees where necessary, and shall prepare and issue all circulars to the members.

32.—One and the same person may hold the office of Secretary and Treasurer.

33.—The Treasurer shall be appointed annually by the Council at their first meeting in each year. The income of the Institution shall be received by him, and shall be paid into Messrs. Lambton & Co.'s bank at Newcastle-upon-Tyne, or such other bank as may be determined from time to time by the Council.

34.—The Treasurer shall make all payments on behalf of the Institution, by cheques signed by two members of Council, the Treasurer and the Secretary, after payments have been sanctioned by Council.

35.—The surplus funds may, after resolution of the Council, be invested in Government securities, in railway and other debenture shares such as are allowed for investment by trustees, in the purchase of land, or in the purchase, erection, alteration, or furnishing of buildings for the use of the Institution. All investments shall be made in the names of Trustees appointed by the Council.

36.—The accounts of the Treasurer and the financial statement of the Council shall be audited and examined by a chartered accountant, appointed by the Council at their first meeting in each year. The accountant's charges shall be paid out of the funds of the Institution.

37.—The minutes of the Council's proceedings shall at all times be open to the inspection of the Ordinary Members and Associate Members.

VI.—General Meetings.

38.—An ordinary general meeting shall be held in February, May and September, unless otherwise determined by the Council; and the ordinary general meeting in the month of September shall be the annual general meeting at which a report of the proceedings, and an abstract of the accounts of the previous year ending July 31st, shall be presented by the Council. The ordinary general meeting in the month of May shall be held in London, at which the President may deliver an address.

39.—Invitations may be sent by the Secretary to any person whose presence at discussions shall be thought desirable by the Council, and persons so invited shall be permitted to read papers and take part in the proceedings and discussions.

40.—Discussion may be invited on any paper published by the Institution, at meetings of any of the Federated Institutes, at which the writer of the paper may be invited to attend. Such discussion, however, shall in all cases be submitted to the writer of the paper before publication, and he may append a reply at the end of the discussion.

VII.—Publications.

41.—The publications of the Institution shall consist of the reports of the meetings of the Institution and of the meetings of the Federated Institutes, and abstracts of patents and other publications relating to mining, metallurgy and allied industries.

The reports of the meetings shall consist of addresses, papers, and the discussions thereon.

The publications may include:—

(*a*) Papers upon the working of mines, metallurgy, applied geology, engineering, railways and the various allied industries.
(*b*) Papers on the management of industrial operations.
(*c*) Abstracts of colonial and foreign papers upon similar subjects.
(*d*) Abstracts of patents relating to mining and metallurgy.
(*e*) Notes of questions of law concerning mines, manufactures, railways, etc.

The following shall be deemed unsuitable, and shall be refused:—

(*a*) Papers containing what is in fact advertising matter.
(*b*) Papers consisting largely of matter already printed in the English language.
(*c*) Papers consisting largely of matter foreign to the objects of the Institution or Federated Institutes.
(*d*) Papers containing matter the publication of which may be deemed injurious to the interests of the Institution or of any Federated Institute.
(*e*) Papers containing matter either libellous or slanderous, or gross misstatements.

42.—The Secretary of the Institution shall be responsible for the editing of the volumes as a whole, for the editing of the reports of the meetings of the Institution and of the Federated Institutes, and for the miscellaneous portion. The Local Secretary of each Federated Institute shall prepare and edit all papers and discussions of such Institute, and promptly forward them to the Secretary, who shall submit proofs to the Local Secretary before publication.

43.—The Council shall appoint a Publications Committee to deal with questions concerning the publications.

44.—A paper for reading at any of the meetings of the Institution shall be sent to the Secretary a clear three weeks before the meeting in question. The Secretary may refer a paper back to the author for compression or alteration, or, in case the matter be deemed suitable, but objection be taken to the mode of expression thereof, he may refer it back to the author for amendment in this respect. If the Author and Secretary cannot agree as to the suitability of the paper, the Secretary shall submit it to two members of the Publications Committee. If both of these approve or reject it, their decision shall be final, but if their views differ it shall be referred to the President of the Institution, whose decision shall be final.

A paper that has been submitted to and approved by the Council of a Federated Institute shall be sent to the Secretary of the Insitution a clear fortnight before the date of the meeting at which it is intended to be read, together with any drawings or illustrations which may be required to accompany it. If desired by the Secretary of the Federated Institute, the Secretary of the Institution will then have the paper printed in galley-form for distribution at the meeting. After the meeting, the paper, revised if necessary by the Secretary in question, shall be returned to the Secretary of the Institution in its final form ready for setting up in pages. If the Secretary of the Institution, at any time, considers the paper unsuitable for appearance in the *Transactions*, he shall notify the Secretary of the Federated Institute, and shall refer it to two members of the Institution Publications Committee, excluding the Secretary or member representing the Institute from which the paper proceeds. If, in the unanimous opinion of these members, the paper is unsuitable for appearance in the *Transactions*, it shall not appear in the *Transactions*, but if their views differ, it shall be referred to the President of the Institution, whose decision shall be final.

45.—Any discussion taking place at any meetings of the Institution shall be reported by a competent reporter. The proof of each speaker's remarks in the discussion shall be sent out to him by the Secretary of the Institution with an intimation that, if not returned corrected within seven days, it will be considered as correct, and the Secretary shall then edit the revised discussion.

The Federated Institutes shall make their own arrangements for reporting the discussions at their meetings and for the correction of the reports of the speakers. The Secretary of each Federated Institute shall forward a clear transcript of the discussion, edited by him, to the Secretary of the Institution for printing. Two galley proofs, together with the manuscript, shall be sent to the Secretary of the Federated Institute for correction, one of which, together with the manuscript, shall be returned ready for printing within seven days of receipt by him, failing which, it shall be considered to be correct.

46.—The Council may accept communications from persons who are not members of the Institution, and allow them to be read at the ordinary or annual general meetings of the Institution.

47.—A paper in course of publication cannot be withdrawn by the writer, without the permission of the Council.

48.—The copyright of all papers accepted for publication in the *Transactions* shall become vested in the Institution, and such communications shall not be published for sale or otherwise without the written permission of the Council.

49.—Thirty copies of each paper and the accompanying discussion shall be presented to the writer free of cost. He may also obtain additional copies upon payment of the cost to the Secretary, by an application attached to his paper. These copies must be unaltered copies of the paper as appearing in the publication of the Institution, and the copy shall state that it is an " Excerpt from the *Transactions* of The Institution of Mining Engineers."

50.—The Federated Institutes may receive copies of their own portion of the publications in respect of such of their members as do not become members of the Institution, and shall pay 10s. per annum in respect of every copy so supplied: and similar copies for exchange shall be paid for at cost price.

51.—A list of the members, with their last-known addresses, indicating the Federated Institute to which they belong, shall be printed annually in the publications of the Institution.

52.—The publications of the Institution shall only be supplied to members, and no duplicate copies of any portion of the publications shall be issued to any member or Federated Institute unless by order of the Council.

53.—The annual volume or volumes of the publications may be sold, in the complete form only, at such prices as may be determined from time to time by

the Council:—To non-members for not less than £3; and to members who are desirous of completing their sets of the publications, for not less than 20s.

54.—The Institution, as a body, is not responsible for the statements and opinions advanced in the papers which may be read or in the discussions which may take place at the meetings of the Institution or of the Federated Institutes.

VIII.—Medals and other Rewards.

55.—The Council, if they think fit in any year, may award a sum not exceeding sixty pounds, in the form of medals or other rewards, to the author or authors of papers published in the *Transactions*.

IX.—Property.

56.—The capital fund shall consist of such amounts as shall from time to time be determined by resolution of the Council.

57.—The Institution may make use of the following receipts for its expenses:—

(*a*) The interest of its accumulated capital fund;

(*b*) The annual subscriptions; and

(*c*) Receipts of all other descriptions.

58.—The Institution may form a collection of papers, books and models.

59.—Societies or members who may have ceased their connexion with the Institution shall have no claim to participate in any of its properties.

60.—All donations to the Institution shall be acknowledged in the annual report of the Council.

X.—Alteration of Bye-laws.

61.—No alteration shall be made in the bye-laws of the Institution, except at a special meeting of the Council called for that purpose, and the particulars of every such alteration shall be announced at their previous meeting and inserted in the minutes, and shall be sent to all members of Council at least fourteen days previous to such special meeting, and such special meeting shall have power to adopt any modification of such proposed alteration of the bye-laws, subject to confirmation by the next ensuing Council meeting.

THE INSTITUTION OF MINING ENGINEERS.

SUBJECTS FOR PAPERS.

The Council of The Institution of Mining Engineers invite original communications on the subjects in the following list, together with other questions of interest to mining and metallurgical engineers.

Assaying.
Boiler explosions.
Bore-holes and prospecting.
Boring against water and gases.
Brickmaking by machinery.
Brine-pumping.
Canals, inland navigation, and the canalization of rivers.
Coal-getting by machinery.
Coal-washing machinery.
Coke manufacture and recovery of bye-products.
Colliery leases, and limited liability companies.
Compound winding-engines.
Compressed-air as a motive-power.
Corrosive action of mine-water on pumps, etc.
Descriptions of coal-fields.
Diamond-mining.
Distillation of oil-shales.
Drift and placer-mining.
Duration of coal-fields of the world.
Electric mining lamps.
Electricity and its applications in mines.
Electro-metallurgy of copper, etc.
Engine-counters and speed-recorders.
Explosions in mines.
Explosives used in mines.
Faults and veins.
Fuels and fluxes.
Gas-producers, and gaseous fuel and illuminants.
Gas, oil and petroleum engines.
Geology and mineralogy.
Gold-recovery plant and processes.
Graphite: its mining and treatment.
Haulage in mines.
Industrial assurance.
Inspection of mines.
Laws of mining and other concessions.
Lead-smelting.
Light railways.
Lubricating value of grease and oils.
Lubrication of trams and tubs.
Maintenance of canals in mining districts.
Manufacture of fuel-briquettes.
Mechanical preparation of ores and minerals.
Mechanical ventilation of mines, and efficiency of the various classes of ventilators.
Metallurgy of gold, silver, iron, copper, lead, etc.
Mining and uses of arsenic, asbestos, bauxite, mercury, etc.
Natural gas, conveyance and uses.
Occurrence of mineral ores, etc.
Ore-sampling machines.
Petroleum-deposits.
Preservation of timber.
Prevention of over-winding.
Pumping machinery.
Pyrometers and their application.
Quarries and methods of quarrying.
Rock-drills.
Safety-lamps.
Salt-mining, etc.
Screening, sorting and cleaning of coal.
Shipping and discharge of coal-cargoes.
Sinking, coffering and tubbing of shafts.
Sleepers of cast-iron, steel and wood.
Spontaneous ignition of coal and coal-seams.
Stamp-milling.
Steam-condensation arrangements.
Steam-power plants.
Submarine coal-mining.
Subsidences caused by mining-operations.
Surface-arrangements at mines.
Surveying.
Tin-mining.
Transport on roads.
Tunnelling, methods and appliances.
Utilization of dust and refuse coal.
Utilization of sulphureous gases resulting from metallurgical processes.
Ventilation of coal-cargoes.
Water as a motive-power in mines.
Water-tube boilers.
Watering coal-dust.
Water-incrustations in boilers, pumps, etc.
Winding arrangements at mines.
Winning and working of mines at great depths.

For selected papers, the Council may award prizes. In making awards, no distinction is made between communications received from members of the Institution or others.

TRANSACTIONS

OF

THE INSTITUTION

OF

MINING ENGINEERS.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
FEBRUARY 9TH, 1907.

MR. J. H. MERIVALE, PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting and reported the proceedings of the Council at their meetings on January 26th and that day.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. ALEXANDER RICHARD BEKENN, Mine-manager, Dundee Coal Company, Limited, Talana, Natal, South Africa.

Mr. EVENCE COPPÉE, Civil Engineer and Managing Director of Collieries, Avenue Louise, 211, Brussels, Belgium.

Mr. ERNEST CHARLES DUNKERTON, Mechanical Engineer, 97, Holly Avenue, Newcastle-upon-Tyne.

Mr. JOHN THOMAS FOULIS, Mine-owner and Mine-manager, Durban House, Ramsey, S.O., Isle of Man.

Mr. FREDERICK JAMES RAINE, Colliery Manager, Etherley Grange Colliery, Bishop Auckland.

ASSOCIATE MEMBERS—

Mr. WILSON ORMROD, Union Buildings, St. John Street, Newcastle-upon-Tyne.

Mr. FREDERICK GEORGE WALEY, The Bellambi Coal Company, Limited, 9, Bridge Street, Sydney, New South Wales, Australia.

ASSOCIATE—

Mr. ALFRED HILL ASKEW, Under-manager, 16, Telford Street, Gateshead-upon-Tyne.

STUDENTS—

Mr. WILLIAM GRACE GRACE, Mining Student, Hall Garth Hall, Winlaton, Blaydon-upon-Tyne, S.O., County Durham.

Mr. HERBERT STANLEY HUNTER, Mining Student, Blakelaw, Kenton, Newcastle-upon-Tyne.

DISCUSSION OF MR. OTTO SIMONIS' PAPER ON "LIQUID AIR AND ITS USE IN RESCUE-APPARATUS."*

Mr. HENRY SIMONIS (London) exhibited the aerolith apparatus, and also made some interesting experiments. Liquid air was preferably stored in vessels designed by Sir James Dewar: these were practically vacuum vessels, but closed by a thick felt-cover through which it was possible for the air to penetrate to a small extent. In such a bottle, liquid air would keep for about 12 days: the evaporation not exceeding 6 per cent. per day. It was easy to transport, and if packed in a case could be forwarded ordinarily by railway, as there was no danger whatever of its exploding. A vessel containing 3½ pints enabled the wearer of the aerolith apparatus to work for 60 to 70 minutes, and a large vessel holding 9 pints was sufficient for 3 hours' work. Liquid air was approximately of the same specific gravity as water, weighing about 62½ pounds per cubic foot and 10 pounds per gallon, and therefore when filled with 9 pints for 3 hours' work, the apparatus (which weighed 14 pounds) would weigh 25 pounds. Liquid air cost about 6d. per gallon, when made with a small plant: and with a larger plant the cost would be considerably reduced. By the Claude system, it was calculated that one horsepower (suction-gas or any other cheap method of producing power being used) would produce 4 gallons of liquid air at a cost of 1½d. per gallon.

Mr. A. L. STEAVENSON (Durham) said that no one had a greater admiration than himself for the skill and knowledge which had been employed to perfect life-saving apparatus during the last 50 years; and yet, at the present day, Mr. G. A. Meyer stated that "it was difficult to understand why the Schwann apparatus had, for so many years, been entirely forgotten."† The

* *Trans. Inst. M. E.*, 1906, vol. xxxii., page . † *Ibid.*, vol. xxxi., page 579.

Fleuss apparatus, and many others, one after another, had all come and gone, because they were found to be of no practical use. At a time when apparatus of this kind was called into requisition, it was necessary for the wearer to scramble over difficult falls and sometimes to squeeze through very small passages, then a man found that his ordinary pit-clothes were an encumbrance; and it was as much as he could do to trail himself through, without having an apparatus to carry on his back. In 1854, Mr. T. Y. Hall, a good practical pitman, brought the subject of rescue-work before the members, and recommended the use of pipes carried along the main roads; and he (Mr. Steavenson) told them to-day that this was the best suggestion that had been made during those 53 years.* In many mines compressed air was being used, and he (Mr. Steavenson) suggested that the pipes should be carried along the main roads and fitted with cocks, so as to give off the air necessary to help any persons shut off. In most cases the members were told that 2 or 3 hours was the utmost limit of time for working a modern rescue-appliance, but Mr. A. M. Henshaw, a thoroughly practical man, had stated that in 37 minutes confusion of mind occurred in the case of a man, who was 200 feet away from everybody else;† he began to lose confidence and would throw off the apparatus, and it was owing to this cause that a man, wearing a rescue-apparatus, was killed at the Courrières mines.‡ The rescuers in that disaster did not save any lives, but they lost one, because the wearer of the apparatus had lost confidence in it. Dr. J. S. Haldane and Mr. Bennett H. Brough approved of the use of rescue-apparatus;§ but they were not practical pitmen, and did not know what it was to travel a fallen road filled with irrespirable air. Mr. W. E. Garforth stated that "considering the interval [60 years] that has elapsed since the first efforts were made, it is disappointing to have to admit that there is not, at the present time, a rescue-apparatus which can be fully relied upon,"‖ and he (Mr. Steavenson) agreed with that conclusion. Mr. Garforth had erected an experimental gallery to test the different forms of rescue-apparatus,¶ but

* *Trans. N. E. Inst.*, 1854, vol. ii., page 87.

† *Trans. Inst. M. E.*, 1906, vol. xxxi., page 615. ‡ *Ibid.*, vol. xxxi., page 610.

§ *Ibid.*, vol. xxxi., page 617. ‖ *Ibid.*, vol. xxxi., page 628.

¶ "Experimental Gallery for Testing Life-saving Apparatus," by Mr. W. E. Garforth, *Trans. Inst. M. E.*, 1901, vol. xxii., page 169.

that was not sufficient. The man who submitted to experiment in such a gallery knew that he could get out of it in 10 seconds, and would not, therefore, lose his confidence in an appliance. Supposing, in a case like the Courrières mines, that the rescue-party got in after much trouble, and that there was, say, a length of 1,500 feet, where there was good air, and then a noxious zone of 1,500 feet; after getting through that, what good purpose could a man wearing a rescue-apparatus fulfil? If he did find a number of men he would be quite unable to bring them through that zone of 1,500 feet of noxious gases. The rescue-party could never do any good work, unless by some means they carried fresh air with them. At the Courrières collieries nothing was accomplished beyond bringing out a number of dead bodies, and no good purpose was served by that. The best plan was to carry the fresh air in with them, and it was the only plan that held its own to-day. The members were much indebted to Messrs. W. N. and J. B. Atkinson for the time and trouble which they had devoted to the question of the prevention of coal-dust explosions. There was no reason why the roads of a mine should not be kept perfectly clean; let them provide sprinkling or spraying apparatus if desired, but certainly let the dust be kept out. As another way of preventing the devastation which takes place, he would advocate that the stoppings be bowed slightly outward, so that they could not be shifted or injured by an explosion; and then they would have a permanent road which no explosion could destroy, and which would enable them to penetrate into a mine whenever it became necessary to do so.

Prof. Henry Louis (Armstrong College) asked whether the apparatus described by Mr. Simonis had ever been tested, so as to ascertain that one gallon of liquid air would actually keep a man supplied with fresh air for 3 hours: this was about 40 cubic feet of air per hour, which was a somewhat small allowance, unless the man got some external air. Tested in the air of an ordinary room, which was drawn back and was available for breathing, this quantity of air might be satisfactory; but, if the apparatus was used in an irrespirable atmosphere, it might easily be too small. It would be interesting, therefore, to know whether any practical tests had been made on this point. He was not at all sure that the differential evaporation, as between

nitrogen and oxygen, which was claimed as an advantage for liquid air, was not rather a disadvantage, as a human being was not constructed so that he could breathe, without discomfort, practically pure nitrogen or oxygen. He also had his doubts as to any benefit that might result from the reserve air-bag, which would become distended with the air which had been breathed by the wearer, and which was (as a last resource in the event of the supply of liquid air running out) to be breathed again, at a time when the man would be fagged and worn out, and, therefore, in special need of fresh air.

Mr. T. E. Forster (Newcastle-upon-Tyne) said that he supported, in a great measure, Mr. Steavenson's views. Rescue-apparatus must be used with a great deal of care and caution. Where a pit had to be reopened after an explosion, the air must be systematically taken in by the explorers. The only use which he saw for the apparatus was in the case where men were overcome with gas in places which could be easily reached; and he knew of an instance, recently, where an appliance of this kind might have saved the lives of two men. The apparatus would also be useful to make explorations in advance of the air, so as to see the direction in which to open out most easily.

Mr. C. C. Leach (Seghill) said that the apparatus would frequently get out of order, and a possible danger would arise, as nobody would know exactly whether it was ready for use, for these appliances were not used everyday.

Dr. Thomas Oliver (Newcastle-upon-Tyne) said that the subject was one in regard to which he could only offer a few remarks of a purely academic character, as he had had no experience whatever of the practical use of rescue-appliances such as were before the members to-day. Still, he was one of those who thought that they should not strike altogether a despondent note. He quite agreed with Mr. Steavenson, if they could carry air into the pits as far as they possibly could, that this was the right thing to do. Experience had already shown the value attached to such apparatus in the case of fire, etc., and he thought that the time had come—for the Courrières explosion had awakened a spirit of public enterprise in the matter, and legislation had already done much for the safety of the men while working—when something would have to be done by science in

regard to the saving of life after explosions. Small quantities of carbon monoxide were sufficient to bring about headache and dizziness, followed in a short time by loss of power in the limbs, which prevented the miner, though most wishful to escape, from getting away, for he would soon fall and die. Mr. Steavenson had alluded to the presence of dead bodies in the pit, and he (Dr. Oliver) thought it was only right to say that there was nothing that proved such a source of discomfort and danger as the large number of bodies in the Courrières mine, all of which were undergoing extremely rapid putrefaction. Whether bodies were left in the pit or not, was a question which would have to be solved by mining engineers themselves. There was certainly the danger that a rescue-apparatus might not work at the proper time; but, without committing himself to an opinion on that matter, the time had come when they were almost obliged to face the question, and see whether something could not be done in the way of using rescue-apparatus. It was perfectly clear that men could not under ordinary circumstances go into parts of the mine where carbon monoxide was; but if by such appliances as these they could go in and stay 1 hour, or longer, and if it could be shown that they could travel through the difficult places mentioned by Mr. Steavenson, a great deal would have been accomplished. He (Dr. Oliver) would not discourage the use of scientific appliances of this kind, but would rather encourage them, and therefore good service had been done by Mr. H. Simonis in coming to explain this apparatus that day. There was not the least doubt that, after explosions, carbon monoxide was the cause of the death of miners. The largest number of men who died in the Courrières mine died from that cause, and very few from shock and burns. It was an interesting point, and he had found the same thing in experiments on animals, that many of the miners died from pneumonia after being rescued. In the case of animals that had not been killed by carbon monoxide, a few days afterwards they died from pneumonia, and, on microscopical examination of the lungs he had found small hæmorrhages in the air-cells of the lungs. If this rescue-work was to be encouraged, he (Dr. Oliver) thought that they should follow Mr. W. E. Garforth's suggestion that training galleries should be erected where men might be put through the same trials as those that they would have to undergo in the mine after an explosion; and, if they could stay in the pit under these

conditions for 2 or 3 hours, he was of the opinion that the value of the apparatus would be quite substantiated.

He (Dr. Oliver) thought that other important facts would come out soon in regard to carbon monoxide. If they were going to train men for rescue-work, there was something in overcoming the initial nervousness alluded to; therefore, men who had been trained were much more likely to go into the pit, knowing how far the apparatus could be relied upon. Perhaps, too, they could be trained to the inhalation, within limits, of carbon monoxide. It was a well-known fact that animals could be exposed to air containing carbon monoxide to the extent of causing 25 per cent. of saturation of the colouring matter of their blood, that is to say, to cutting off one-quarter of the respiratory power, and with the remaining three-quarters they got on very well. With carbon monoxide there was at first a certain amount of blood-destruction, but the red blood-corpuscles subsequently became increased, and the respiratory power was quite sufficient to overcome the deficiency. These animals lived and had excellent health, they improved in weight, the blood improved in quality; and they could, by gradually increasing the percentage of carbon monoxide, carry it to 35, or even 45, per cent., and the animals would still live, while one which had not been so trained would die in a very short time if placed in such conditions. He therefore threw out the suggestion that, if Mr. Garforth's proposed galleries were erected and Messrs. Nasmith and Graham's experiments* were confirmed *re* carbon-monoxide poisoning, a gradual acclimatization of men to mixtures of carbon monoxide might be shown to be possible within certain limits, as in the case of animals.

Mr. C. C. Leach (Seghill) asked whether Dr. Oliver advocated that all who went down the mine should be taught to breathe an atmosphere containing a high percentage of carbon monoxide.

Dr. T. Oliver said that he had only stated what had been done with animals: he did not venture himself to suggest that the men should do so, but it was worth consideration. If men could become acclimatized to carbon monoxide, it would prove of great value, especially if a certain amount of fresh air, in cylinders, could be carried in by the rescue-party for the entombed miners.

* "The Haematology of Carbon-monoxide Poisoning," by Mr. G. G. Nasmith and Mr. D. A. L. Graham, *Journal of Physiology*, 1906, vol. xxxv., page 32.

Mr. C. C. LEACH remarked that they would probably want to send in only a few men, but how were the hundreds already in the mine to be saved?

Dr. T. OLIVER said that fresh air or cylinders of oxygen should be carried in by the rescue-parties.

Mr. HENRY SIMONIS, replying to the discussion, said that Mr. A. L. Steavenson's remarks were directed against all rescue-apparatus; but, after Dr. Oliver's remarks, he did not think that he need reply to him. The use of pipes was an old idea, and, only about a month ago, he discussed with Dr. J. S. Haldane the possibility of leading liquid air in pipes to be used in mines, and sprayed by sprinklers, as water was used in combatting a fire, that was to say, whether it would be possible, with certain appliances, to arrange that the liquid air should be automatically released, and the liquid air could then be poured into the pit so as to purify the air and produce a breathable atmosphere at the same time. He did not think that it would be possible to reduce the size and encumbrance of the aerolith apparatus below its present dimensions: it was certainly, by far, the lightest and most compact form that had yet been introduced. With regard to practical experience with the apparatus, a complete installation, at one of Baron Rothschild's collieries in Austria, had been working for about 3 months; and another similar plant had been erected and would be completed at another colliery within a few days. It had been proved thereby that 3 hours' work could very easily be performed with the apparatus, even allowing a wide margin, when charged with 1 gallon of liquid air, the equivalent of 120 cubic feet of breathable air, and this was more than sufficient for any man working for 3 hours. He (Mr. Simonis) did not put any stress on the reserve-bag; it was only the very last resource possible, and experiments had shewn that the air contained in this bag was still holding a larger percentage of oxygen than ordinary atmospheric air. There was no possibility of the apparatus going out of order, and as there was not a single valve nor complication of any kind, the apparatus was bound to work the moment that liquid air was poured in, although it might have been lying untouched for any length of time. It did not follow that pure oxygen would do a man any harm, because a man's lungs were so constructed that they could not take more than a certain amount

of oxygen, so that any excess would simply flow away with the air exhaled, and so do no harm whatever. Dr. Oliver's remarks about carbon monoxide were very interesting to him personally, and absolutely new; and he would try to get some men to try the suggested experiment. A plant capable of producing about 0·9 gallon of liquid air per hour would cost from £300 to £400, and it would require from 6 to 8 horsepower, so that according to the cost of the power, the cost of producing liquid air could be calculated. Under conditions, not at all favourable, the cost would not exceed 2s. 4d. per hour or 2s. 7d. per gallon.

Mr. T. C. Futers asked whether this cost included interest on the cost and depreciation of the plant.

Mr. H. Simonis said that the manufacture had been sublet, and the cost, therefore, included everything possible—and probably a considerable profit as well.

The President (Mr. J. H. Merivale) thought that there was room, both for the carrying out of Mr. Steavenson's suggestion, and for such appliances as those put forward by Mr. O. Simonis, Mr. G. A. Meyer, Mr. W. E. Garforth, and others; more especially if they could be perfected or brought nearer to perfection. Dr. Oliver's remarks had been most interesting, and he had no idea that it was possible for an animal to become immune to carbon monoxide, and to breathe air containing that gas. Consequently, if an animal could breathe a large percentage of carbon monoxide, it seemed reasonable to suppose it possible that a man could become accustomed to breathe much larger proportions than at present. This was a most important point, and no doubt would be followed up by those gentlemen who were making a study of this question.

Mr. T. J. Gueritte's paper on "Ferro-concrete and its Applications" was read as follows:—

FERRO-CONCRETE AND ITS APPLICATIONS.

By T. J. GUERITTE, C.E., B.Sc., M.Inst.C.E. (France).

Concrete, as is well known, has a high coefficient of resistance to compressive strains, but its resistance to tensile or shearing strains is low, and it would be very uncertain to rely upon it. On the other hand, iron and steel have a high resistance to com-

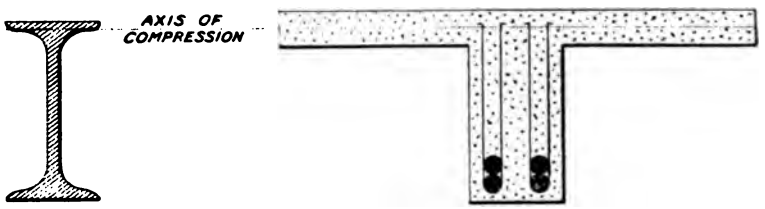

Fig. 1.—Ferro-concrete and Iron Beams.

pressive tensile and shearing strains. It is, therefore, a natural thing to try to compensate the shortcomings of concrete by the use of steel: that is, to use concrete in a structure wherever there is compression; and to meet the shearing and tensile stresses where they occur by means of iron or steel.

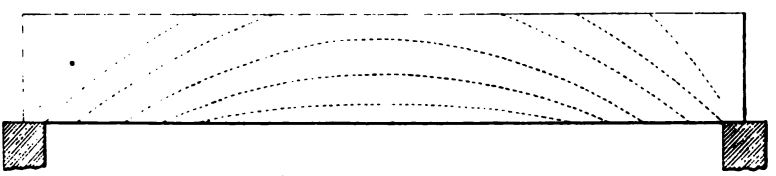

Fig. 2.– Shearing-stresses in a Beam.

Such is, in a few words, the principle of ferro-concrete construction. If, therefore, a ferro-concrete beam be compared with a rolled joist (fig. 1), the steel rods placed in the lower parts represent the line of traction which, in the rolled joist, is constituted by the lower flange. The concrete which forms the flooring above the beams is relied upon to resist the compressive strain, and may be considered as playing the part of the upper

flange of the rolled joist. The web is formed by the concrete, which encases the bars and connects the axis of compression to the axis of tension. But concrete alone would not be sufficient for the purpose, as it would not resist the shearing stresses.

The effect of shearing stresses is to provoke the formation of cracks in the beam. These cracks make an angle of nearly 45 degrees with the horizontal near the supports; this angle decreases from the supports to the middle of the span (fig. 2). In order to meet these stresses, stirrups made of hoop-steel (fig. 3) are fixed on the lower bar, and, being disposed vertically (fig. 4), connect the axis of compression with the axis of tension

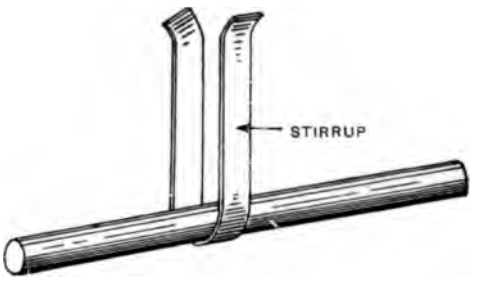

FIG. 3.—STIRRUP AND ROD.

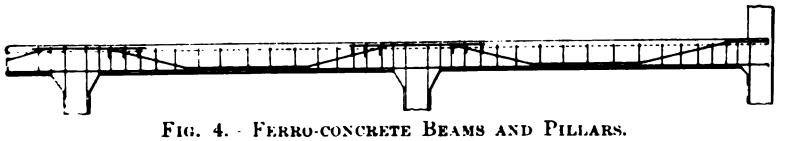

FIG. 4. - FERRO-CONCRETE BEAMS AND PILLARS.

and oppose the formation of cracks which, without them, would be the result of the action of shearing stresses. In most ferro-concrete structures the beams are continuous, and practice shows that it is possible and certainly very economical to consider them as semi-fixed at both ends instead of supported only. But then tensile stresses appear at the upper part, near the supports. Steel will therefore be necessary there, and one of the best ways to provide for it is to bring diagonally to the upper part of the beam some of the bars which were at the bottom in the middle of the span and which are not required any more near the supports: for in such a beam there is near the supports no tensile strain on the lower parts, as it is confined to the upper portion. This disposition (fig. 4), and the triangle thus formed, gives great rigidity to the whole structure.

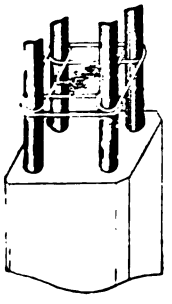

FIG. 5.—FERRO-CONCRETE PILLAR.

The writer's remarks about beams applies, of course, equally to the flooring itself which may be considered as a beam, very wide and of small depth.

FIG. 6.—DWELLING-HOUSE, RUE DANTON, PARIS.

The pillars form the most important component parts of a ferro-concrete building. A pillar, generally speaking, is submitted only to compressive strains, and therefore both concrete and steel are suitable for its formation (fig. 5). Bars varying in

number and size are embedded in a block of concrete: therefore both elements work together, and each of them takes part of the load to be supported.

The first applications of ferro-concrete construction were, the writer believes, made in the shape of fireproof floors, pillars and walls. But these applications belong more to architecture (fig. 6) than to engineering, and he will not, therefore, add anything to the general principles already described.

FIG. 7.—WAREHOUSE FOR CO-OPERATIVE WHOLESALE SOCIETY, LIMITED, NEWCASTLE-UPON-TYNE.

There is a question which the writer thinks is of interest, namely, that of very bad foundations in which settlements are anticipated on account, for instance, of colliery-workings in the immediate vicinity. Here, ferro-concrete has been found to be a most useful and economical solution of the problem. To illustrate this view, the writer will take the case of a building entirely built of ferro-concrete on the Quay, at Newcastle-upon-Tyne. This is an eight-storey building, and each floor has to carry the

enormous weight of 6 cwts. per square foot (fig. 7). In addition to this, the flat roof is calculated for the storage of empties and non-perishable goods. The result is that the pillars in the basement have to carry loads amounting to 600 tons, and some of them have even to support nearly 900 tons. Now, the foundations tions being composed of slush, peat, quicksand, etc., to a depth of 60 feet, it was evident that the foundations had to be formed either by piles driven to that depth or by cylinders, at a very great cost; it was, therefore, decided to adopt ferro-concrete. A general ferro-concrete platform was built over the whole area, spreading

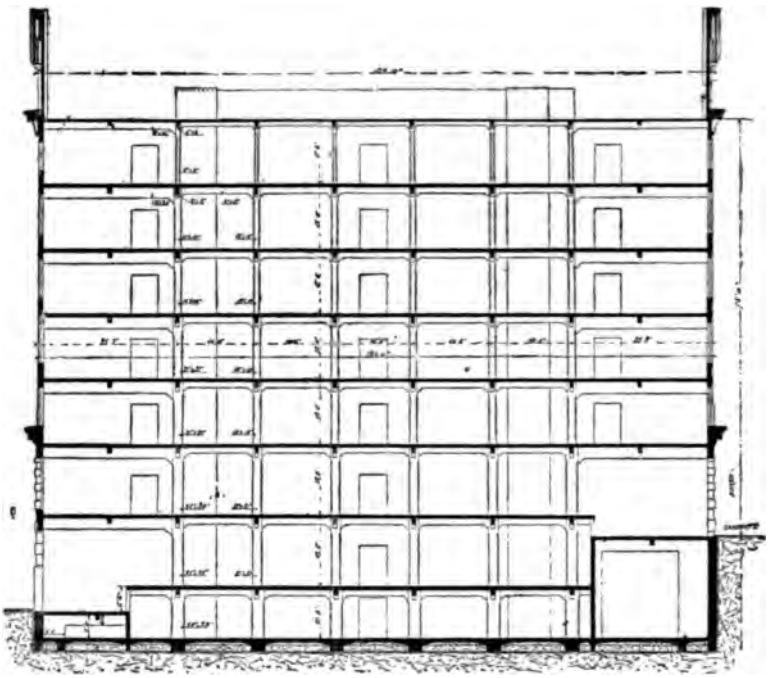

FIG. 8.—LONGITUDINAL SECTION OF WAREHOUSE. SCALE, 36 FEET TO 1 INCH.

the load at the rate of 28 tons per square yard. Of course, such a platform would have been inadequate by itself to withstand the enormous strain imposed; but by means of pillars and walls it is connected to the remainder of the building, and the whole structure forms a monolithic block, a sort of huge box-girder, 100 feet high and with a span of 130 feet. It was assumed that the whole block would sink 6 inches below its original level and without deterioration. The sinking process was carefully

watched, and it was found, ultimately, that the building had sunk as anticipated, and without ill effect on its strength (figs. 8 and 9).

Fig. 10 shows the effects of the subsidence of made ground at Bizerta, Tunis, on ferro-concrete buildings. These were restored to a horizontal position, at a lower level, by excavations.

The construction of water-tanks (fig. 11) and reservoirs offers a vast field to ferro-concrete. A list of reservoirs built on the Hennebique system alone, during the last seven years, numbers

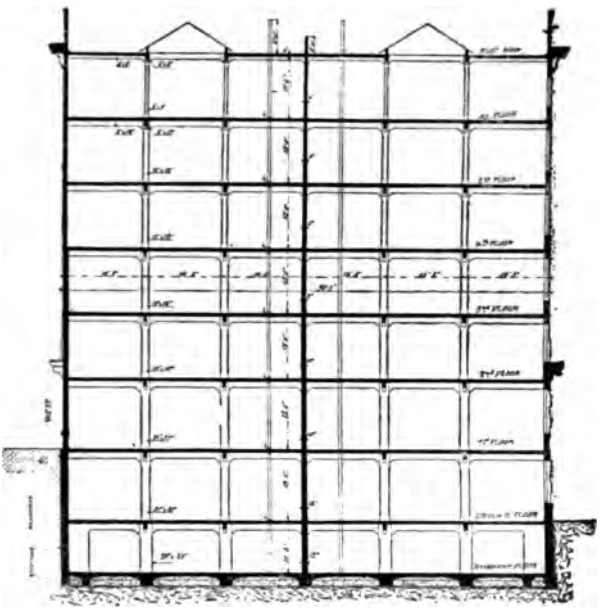

FIG. 9.—CROSS-SECTION OF WAREHOUSE. SCALE, 36 FEET TO 1 INCH.

over 1,000. This, it seems, would tend to give faith to the most sceptical. The flat roofs of ferro-concrete buildings are in many cases used as water-tanks.

A form of reservoir, of which a word must be said, is grain or coal-silos, or hoppers, the latter being of special interest (figs. 12, 13 and 14). They are calculated as a sort of reservoir, due allowance being made for the friction of the grain or coal on the walls.

Fig. 15 shows the entrance to a large culvert, 32 feet wide, at Newcastle-upon-Tyne, forming a new course for the Ouse-

FIG. 10.—BUILDINGS FOR MANUFACTORIES, BIZERTA, TUNIS.

burn. Fig. 16 shows a ferro-concrete aqueduct for conveying water to the water-power plant at the Simplon tunnel-works.

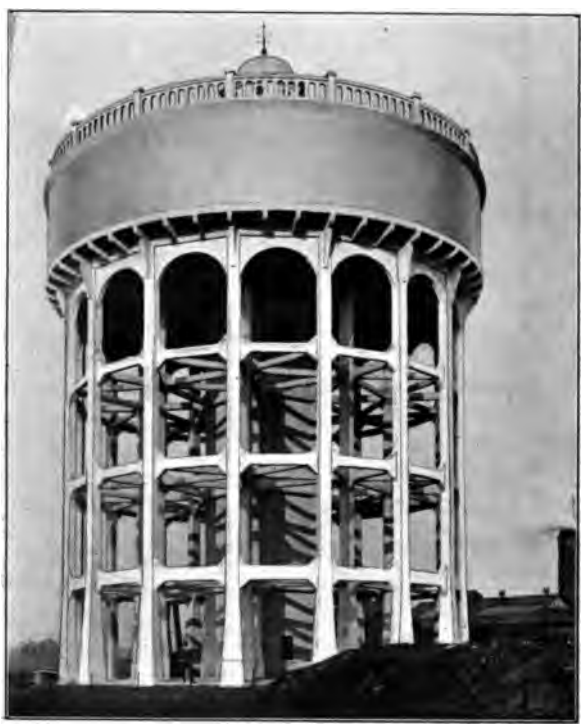

FIG. 11.—WATER-TANK AT NEWTON-LE-WILLOWS.

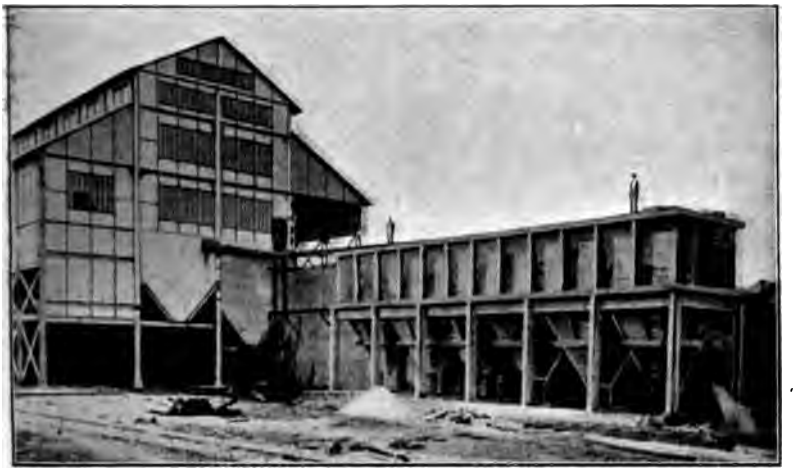

FIG. 12.—COAL-HOPPERS AT CARMAUX COLLIERIES, FRANCE.

Ferro-concrete bridges have very nearly the same appearance as metallic bridges, and are, indeed, constructed on nearly the same principles. They have a very small rise, varying from 4 per cent. to 10 per cent. of the span. The total thickness at the key is

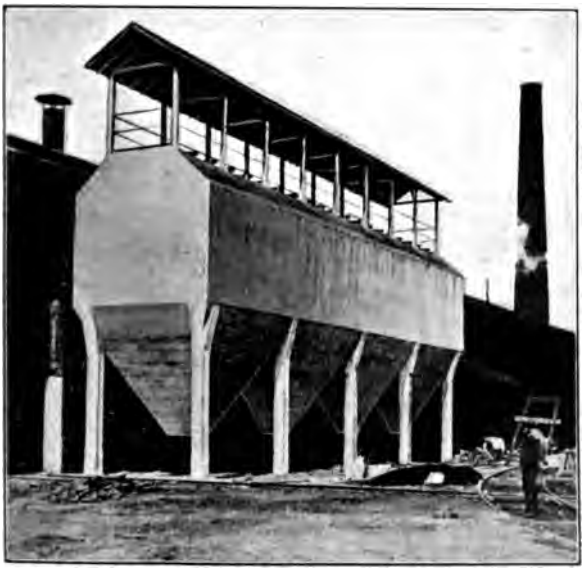

FIG. 13.—COAL-HOPPERS AT LENS COLLIERIES, FRANCE.

very small. In the Liége bridge, for instance, at the middle arch, with a span of 184 feet, the total thickness of the key is only 13 inches from the intrados of the arch to the upper part of the foot-path (fig. 17). It is evident that such a light structure offers a

FIG. 14.—COAL-WASHING PLANT AT ANICHE COLLIERIES, FRANCE.

greater space for the passage of floods, and it is possible, therefore, to lessen by a few feet the distance between the road-level and the ordinary water-level. The consequences being a lower

radient, and a saving in the abutments and filling for he approaches of the bridge. Another point well worthy of con-ideration is that the weight of a ferro-concrete bridge is much maller than the weight of a masonry bridge, and the foundations onsequently are less costly.

Some apprehension was formerly entertained as to the security ffered by ferro-concrete bridges. However, the writer finds that luring the last seven years more than 800 bridges have been uilt in Hennebique ferro-concrete, and most of these bridges ave been severely tested.

FIG. 15.—OUSEBURN CULVERT, NEWCASTLE-UPON-TYNE.

Ferro-concrete has also been applied to river and marine works (fig. 18). Most of these works contain piles and sheet-piles of ferro-concrete. Their principle of construction is some-what analogous to that of pillars. They are consituted by a certain number of bars embedded in concrete, and maintained at the required distance apart by means of distance-pieces. Their section may vary according to the requirements from, say, 4 inches by 8 inches for very small sheet-piles, up to 20 inches square. Their length when moulded in one piece has attained

more than 65 feet. The question of weight alone prevents the moulding of longer piles in one piece; but, in cases where greater lengths are required, there are means of connecting piles moulded

FIG. 16.—AQUEDUCT AT THE SIMPLON TUNNEL, SWITZERLAND.

beforehand, insuring a very rigid joint, and it is possible to drive ferro-concrete piles almost to any depth.

Architects sometimes object to ferro-concrete, owing to the supposed plainness of its appearance. Although engineers are

not concerned so much about æsthetics, the writer happens to

FIG. 17.—BRIDGE AT LIÉGE, BELGIUM.

know that ferro-concrete lends itself to elaborate ornamentation

in buildings (fig. 6), and as regards bridges, jetties, reservoirs, etc., it compares very favourably with other materials.

It is sometimes argued that ferro-concrete is too new a material. But ferro-concrete structures have been erected now for fifteen years without showing any sign of decay, and have been erected by thousands. Continuous vibrations, which were at first supposed to be very detrimental to ferro-concrete, do not affect it in the least. A most serious enquiry has been made on this particular point by order of the French Government, and the

FIG. 18.—COAL-SHIPPING QUAY AND JETTY, SOUTHAMPTON.

conclusions of the report are absolutely positive. The writer need hardly state that the legend, that in course of time the steel bars become rusted in concrete and lose a great part of their strength, has been abandoned long ago, it having been proved that oxide of iron cannot exist in contact with cement. Besides, every-day practice shows that rusted bars embedded in concrete will be, in the course of a month or so, as bright as when leaving the rolling mill, the rust having been deoxidized by the formation of ferrite of calcium, which forms a protective skin all round the bars.

The adherence of concrete to iron has also been questioned. But the coefficient of adherence has now been determined, and its value is such that it justifies the practice of ferro-concrete specialists who reckon on concrete alone to make the junction between the different metallic parts of the structures. The writer means that two bars, which have to be connected, are merely set close to each other in the moulds and embedded in the concrete.

FIG. 19.—COAL-HOPPERS AT SOUTHAMPTON WITH A CAPACITY OF 4,000 TONS.

As regards the expansion of concrete and steel, their coefficients are identical up to the fifth decimal figure, and in practice it may be assumed that they are equal; consequently, in the fiercest fires, ferro-concrete resists without losing any of its qualities of strength and elasticity.

Amongst the other advantages of ferro-concrete are its cheapness, its rapidity of execution, the solidarity between all the

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Amongst the other advantages of ferro-concrete are its cheapness, its rapidity of execution, the solidarity between all the

elements of the structure, and its durable properties which obviate almost entirely subsequent expense in upkeep, painting, etc., its absolute immunity against the attack of wood-worm, dry-rot, and damp-rot, and the like.

The writer will close by repeating the words by which the chairman of the committee of research on ferro-concrete, instituted by the French Government, characterized ferro-concrete: — "Masonry has its weakness, which is insuperable, namely, the joint; metallic structures have also an insuperable source of weakness, the rivet; ferro-concrete presents no joints and does not rely on rivets, it is not made of pieces jointed or fitted together, it is a block."

The PRESIDENT (Mr. J. H. Merivale) moved a vote of thanks to Mr. Gueritte for his instructive paper.

Prof. H. LOUIS seconded the resolution, which was cordially approved.

THE SOUTH STAFFORDSHIRE AND WARWICKSHIRE INSTITUTE OF MINING ENGINEERS.

GENERAL MEETING,
HELD AT THE UNIVERSITY, BOURNBROOK, BIRMINGHAM,
FEBRUARY 12TH, 1907.

MR. F. A. GRAYSTON, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting and of Council Meetings were read and confirmed.

The following gentlemen were elected:—

ASSOCIATE MEMBER—
Mr. W. GORDON GREENBOW, Hednesford.

STUDENT—
Mr. GAVIN HILDICK SMITH, The University, Birmingham.

Prof. C. LAPWORTH read the following paper on "The Hidden Coal-fields of the Midlands":—

THE HIDDEN COAL-FIELDS OF THE MIDLANDS.

By Prof. CHARLES LAPWORTH.

The day was when it was believed that each of the visible coal-fields in the Midlands was a single and complete basin in itself, whose coal-seams and associated strata had no relation to those of the other visible coal-fields of the region. But that primitive opinion had long since been disproved by the advance of geology; and the view now generally accepted, even among those who have only a passing acquaintance with the science, is that all the visible coal-fields are simply the exposed coal-bearing portions of what once was a continuous sheet of Carboniferous strata, originally laid down in one and the same grand area of deposition, and afterwards covered by a similarly continuous sheet of red Triassic rocks. These two rock-sheets, the dark Carboniferous below and the red Triassic sheet above, became bent and folded by earth-crust movement into broad arches and troughs. From the crests of these arches, the Triassic rocks have been swept off by denudation, laying bare the Coal-measures below. These bared portions now form the visible coal-fields.

But, in the broad troughs and depressions between these arches, the red rocks of the Triassic sheet still remain intact, while beneath that sheet, at depths which increase, broadly speaking, in passing outwards from the visible coal-fields towards the central parts of the depressions, the Coal-measure sheet is preserved, and forms an enormous hidden coal-field or coal-fields underlying all the country intervening between one visible coal-field and another.

This newer generalization is certainly a great advance upon the older one, and it has, at all events, the advantage of bringing into prominence one of the chief economic results of geological mapping and research among the Midland Coal-measures during the last 50 years, at the same time that it indicates, in a broad way, the mode of origin and the present relations of the visible and the hidden coal-fields of the district.

But while this view is adequate enough as a working generalization, it is insufficient if the details be examined; for it takes no account of the minor complications which enter into the matter. The Coal-measure sheet is by no means uniform everywhere either in character or in thickness; for, in the northern parts of the Midlands, as in Lancashire and North Staffordshire, the Coal-measures are a mile in depth and their middle member is exceedingly rich in workable coal-seams, while towards the southern parts the sheet becomes much thinner and finally all that remains is a mass of sandstones and shales from which coal-seams are absent or, if present, are thin and poor.

The red Triassic rock-sheet certainly overlies the dark sheet of the Coal-measures wherever the two are found in association, but there are large districts of country, like some near Charnwood, where the Coal-measure sheet was swept off before the Triassic sheet was laid down, and where, as a consequence, hidden coal-fields cannot possibly be met with.

It is true that a visible coal-field, like that of South Staffordshire, may occur on the crest of a denuded arch and be everywhere more or less surrounded by the Triassic rock-sheet with its promise of hidden coal-fields. But there are far more cases where, as in North Staffordshire, the visible coal-field lies on one of the flanks of an arch, or, as in the county of Denbigh, lies on the outer rim of the region, so that the Triassic rocks occur on only one of its sides. Again, even where the visible coal-fields are fringed by Triassic rocks with hidden coal-fields below, these hidden coal-fields are sometimes cut off by faults of enormous throw, like the boundary-faults of the Black Country; faults sometimes so great as to deter mining enterprise beyond them down to the present time, as in the case of the great red-rock fault of the Potteries country.

If, however, allowances are made for such difficulties and complications, the generalization stands. All the productive Coal-measures of the Midlands are constituent parts of what once was the same sheet of ordinary sediments; and, where they now remain preserved under the newer formations, they form a series of hidden coal-fields collectively larger than all the visible Midland coal-fields combined.

The story of the gradual accumulation of our present know-

ledge of the Midland Coal-measures, visible and hidden, reaches far back into the earlier half of the last century. To no British geologist does the present acceptance of the view, that all the Coal-measures and their coal-seams are ordinary sediments and follow the wellknown laws of deposition, arrangement and continuity of such sediments, owe more than to the late Prof. J. B. Jukes, whose memoir on the South Staffordshire coal-field* still remains classic. The detailed mapping of the coal-fields and their surroundings by the officers of the Government Geological Survey has shown how naturally the characters and distribution of the Carboniferous formations and subformations fall into line and order under this simple view. It lies at the foundation of the inferences drawn by the geologists of the First Royal Coal Commission in all that concerns the probable positions and resources of the concealed coal-fields then untested; and all the underground extensions of our coal-fields won or proved since that time fall within the areas then suggested. The brilliant discoveries and speculations, made by our latest generation of Carboniferous geologists—Messrs. Walcot Gibson, Thomas Crosbee Cantrill, Wheelton Hind, John Thomas Stobbs and Percy Fry Kendall—during the last few years, go to show that this view is becoming applicable to yet finer and finer detail. Indeed, the day has now arrived when, not content with establishing the original continuity or otherwise of the subformations of the Coal-measures, geologists will make an endeavour to fix the details of the extent and range of the smaller zones, and it may be of many of the individual coal-seams themselves.

The Midland mining community has been by no means slow to follow up the results of geological discovery and speculation, and to extend its mining enterprise well outside the limits of the visible coal-fields into the hidden coal-fields beyond. The late Mr. Henry Johnson might almost be called the British pioneer in this respect, and his conquest of the hidden coal-field of Sandwell in 1874 was as bold and startling at the time as it was successful in its results. In South Staffordshire alone, the total area of hidden coal-fields below the red ground already

* "On the Geology of the South Staffordshire Coal-field," by Prof. J. Beete Jukes, *Museum of Practical Geology and Geological Survey: Records of the School of Mines and of Science applied to the Arts*, 1853, vol. i., page 149.

practically proved by workings, shafts or borings in the Cannock Chase country to the north, the Sandwell-Hampstead-Langley ground to the east, and the Baggeridge-Four Ashes country to the west, may be roughly set down as almost equal to one-third of the total extent of the original visible coal-field itself. During the last 50 years also, the mining community of Leicestershire and East Warwickshire have doubled the previously known extent of their coal-mining country by opening out the hidden Coal-measures below the red ground; and the hidden coal-field, claimed by mining authorities as already proved, below the red ground to the east of the Yorkshire-Nottinghamshire coal-fields, amounts to more than 500 square miles.

But if geologists are right in the conclusions that they draw from the facts won by their researches, the total area of the hidden Midland coal-field hitherto entered upon, or even fairly proved by shafts or borings, is but a fraction of that which actually exists. As the output of coal increases and the visible coal-fields begin to show signs of exhaustion, two questions become more pressing year by year:—(1) Where do the untested hidden coal-fields occur; and (2) which among them are so situated and so prolific in coal-seams that they offer the greatest promise of commercial exploitation and profit?

The answers to these questions, so far as they can be answered in the present state of geological knowledge and engineering practice, are fully set forth in the various local reports of the recent Royal Commission on Coal-supplies which deal with the coal-resources of the proved coal-fields, and in the General Report on the Concealed Coal-fields prepared for Lord Allerton by the Geological Committee.* The reports, published singly, at low prices, should be studied by all who are interested in the subject. It is only necessary, therefore, to summarize the present state of knowledge and speculation so far as the Midlands are concerned, and refer to these reports for details.

The original boundaries of the area of deposition in which the Midland Carboniferous strata were laid down are unknown, but the main or productive Coal-measures apparently die out altogether towards the south along a curved line drawn from the

* *Final Report of the Royal Commission on Coal-supplies*, 1905, parts ii. to ix. inclusive.

Wash, to the south of Leicester and Coventry, and thence through the Lickey Hills, the Forest of Wyre, and the Clee Hills, to the Longmynd. This line may be looked upon as broadly marking the effective southern limit of the region. Eastwards, the area appears to have extended through Lincolnshire to the shores of the German Ocean, and westwards its deposits still survive as far as the hills of the counties of Denbigh and Flint. Northward, the region includes at least all the southern parts of the Pennine chain from about the latitude of York. Within the limits of the Midland region, thus extended, lie the visible coal-fields of Lancashire, Yorkshire, Nottinghamshire, North Staffordshire and South Staffordshire, Leicestershire, East Warwickshire, Coalbrookdale, Denbigh and Flint, and a few others of minor note.

The typical district of the Coal-measures of the Midlands is the coal-field of North Staffordshire, where the strata have been mapped and studied in detail by the officers of the Geological Survey and by various local geologists. They have been recently classified and described by Mr. Walcot Gibson in the Survey Report on the North Staffordshire coal-field* and their correlation has been discussed by him and others in various geological papers and memoirs. According to these authorities, the Coal-measures of North Staffordshire attain a thickness of from 5,000 to 7,000 feet. For the present purpose, they are most conveniently regarded as being made up of two main divisions:—A Lower Coal-measure group, which may be called the productive Coal-measures, as they contain nearly all the workable coal-seams of the district; and an Upper group, which may be called the non-productive Coal-measures, for although they contain occasional coal-seams, these seams are thin and of but little commercial value.

The productive Coal-measures are sometimes regarded as falling into two sections:—A lower section broadly referred to as the Lower Coal-measures, and a higher section broadly referred to as the Middle Coal-measures. The section of the Middle Coal-measures contains the richest seams of coal in the district, and its highest band is that known locally as the Bassey mine.

* *Memoirs of the Geological Survey of England and Wales: The Geology of the North Staffordshire Coal-field*, by Mr. Walcot Gibson, 1905, pages 38 to 55.

The non-productive Coal-measures which follow have a collective thickness of 2,000 feet, and are more usually referred to as the Upper Coal-measures. They are arranged in four successive groups:—(1) Black-band group at the base, from 300 to 450 feet thick; sandstones and mottled clays, with a few very thin coal-seams and many rich ironstones. (2) Etruria Marls, from 800 to 1,100 feet thick; mottled and purple marls and clays, with coarse green grits and sandstones. (3) Newcastle-under-Lyme group, from 300 to 350 feet thick; grey sandstones and shales, with four thin seams of coal. (4) Keele series, over 700 feet thick; red and purple sandstones and clays, with rare and thin coal-seams. The Keele beds were formerly mapped as Permian, but they are now classed as the highest member of the non-productive or Upper Coal-measures.

Mr. Walcot Gibson and others have shown within the last few years that the whole of this non-productive series forms a geological unit, and must in future be looked upon as such. Its four divisions are all conformable among themselves, and graduate the one into the other. They all contain intermittent coal-seams, although these are of little value. From the bottom to the top of the series, there is a recurrence of thick beds of brightly coloured clays and marls, of thin limestones with Entomostraca and occasional examples of *Spirorbis*, the *Spirorbis*-bands becoming more important towards the summit of the series. Not only is this non-productive series thus shown to be a definite Coal-measure series following naturally after the productive Coal-measures, but its distinction from the true Permian beds has been made evident by the discoveries in East Nottinghamshire. In a boring* at Thurgarton, 10 miles north-east of Nottingham, these non-productive Coal-measures were found to underlie unconformably the typical Permian rocks of that district. These true Permian rocks there consist of the Magnesian Limestone series. Below the unconformable base of this series were met in descending order:—(1) 188 feet of red sandstones and marls containing Carboniferous plants: answering to the Keele beds; (2) grey sandstones and shales containing a thin seam of coal: answering to the Newcastle

* "On the Character of the Upper Coal-measures of North Staffordshire, Denbighshire, South Staffordshire and Nottinghamshire; and their Relation to the Productive Series," by Mr. Walcot Gibson, *The Quarterly Journal of the Geological Society of London*, 1901, vol. lvii., pages 262 to 264.

group; and below these (3) the ordinary grey Coal-measures of the visible coal-field. Thus, the non-productive series of North Staffordshire, including the Keele beds or the so-called Midland or Salopian Permian, was shown to belong to the Carboniferous system by its conformity with the productive Coal-measures beneath, and to be distinct from the true Permian by its unconformity with the Magnesian Limestone series above.

In the Lancashire coal-field, the productive coal-measures have a thickness varying from 4,000 to 6,000 feet. The non-productive measures are also well developed, attaining a thickness of from 1,600 to 3,500 feet; but, as yet, their component divisions have not been worked out.

In the Denbighshire and Flintshire coal-fields the productive Coal-measures are thinner than in North Staffordshire, but the thickness of the non-productive measures is greater. The Black-band series, at the base of the latter, has not yet been identified in the Denbigh district, but the Newcastle group, the Etruria Marl series and the Keele beds are all present and fully developed.*

In the South Staffordshire coal-field, the productive Coal-measures are well represented, as are also the non-productive measures above. The productive Coal-measures attain a thickness of nearly 2,000 feet in the northern part of the coal-field, but thin down to a fourth of that thickness perhaps in the Dudley and Oldbury district, and die out apparently altogether as they approach the Lickey Hills. The non-productive series is collectively thicker than in North Staffordshire. The Etruria Marls of North Staffordshire are represented by the Brick-clay series of Oldbury, with its included green and grey Espley grits: the Newcastle series by the Halesowen sandstone group; and the terminal red-rock group or Keele series is represented by the so-called Permian sandstones and marls of the Lickey Hills, Warley and Enville.

In the Warwickshire district, the productive Coal-measures decrease from more than 1,000 feet in the northern parts of the coal-field to less than half that amount where they are lost to sight near Wyken and Coventry. The Etruria Marls are

* "On the Character of the Upper Coal-measures of North Staffordshire, Denbighshire, South Staffordshire and Nottinghamshire; and their Relation to the Productive Series," by Mr. Walcot Gibson, *The Quarterly Journal of the Geological Society of London*, 1901, vol. lvii., pages 260 to 261.

represented by the Warwickshire Brick-clay group, worked for brick-making near Stockingford and marked by the occurrence of the usual Espley beds. The Halesowen group is represented by certain grey sandstones and coloured clays, which follow in the Stockingford country and have the usual *Spirorbis*-bands at the summit. The Keele series is here more fully developed than in any other district in the Midlands. These beds include most, if not all, of the strata hitherto laid down on the Geological Survey maps as Permian; they spread out over all the ground lying to the west and south of the coal-field from Kingsbury to Kenilworth and Leamington, and are estimated to have a maximum thickness exceeding 2,000 feet.

In the Coalbrookdale region, the productive Coal-measures or "sweet coal" group, as they are locally called, are relatively thin, about 220 feet at the most. They are followed by a series of non-productive measures, consisting of grey sandstones and coloured marls, with a few thin sulphurous coals and some *Spirorbis*-bands. By many authorities, including Mr. Daniel Jones and Mr. W. J. Clarke, this non-productive series is regarded as lying unconformably on the productive measures; and it certainly overlaps south-westwards directly upon the old pre-Carboniferous floor. The same relations of overlap or unconformity also obtain throughout the whole of the southern extension of the Coalbrookdale region down the Severn and into the Forest of Wyre, where the sweet coals have been recognized only in one small district near Highley. All the rest of the Carboniferous ground is apparently occupied by the Upper Coal-measures with their sulphurous seams and local bands of *Spirorbis*-limestone.

In the coal-fields of Lebotwood and Shrewsbury, the Upper Coal-measures alone appear to be present. A few hundreds of feet of grey sandstones and shales, with a few thin coal-seams and *Spirorbis*-bands rest at once upon the pre-Carboniferous floor, and these grey beds graduate conformably upwards into the red sandstones and marls hitherto mapped as Permian, but which are, the writer imagines, the representatives of the Keele series of the north.

In the East Leicestershire coal-field, no Upper Coal-measures appear to be present. This is also the case in the visible portion of the Nottinghamshire coal-field; but, as has already been

seen, they come in to the south-eastwards in the hidden coal-field under the post-Carboniferous cover, as proved in the boring at Thurgarton.

Even from this hasty summation of the present knowledge of the grouping and extent of the Coal-measures of the Midland coal-fields, it is evident that these Coal-measures as a whole were laid down in one and the same grand region of deposition. Judging from the fact that the productive measures are thickest at the north of this region and thin away and finally die out at the south, the area must have been one in which the rate of depression was much more rapid in the north than in the southern direction. It would almost appear, indeed, that during Lower and Middle Coal-measure times the southern margin of the region remained above water. During the Upper Coal-measure period, however, the depression seems to have been a more general one, for the Upper Coal-measures appear not only to have been deposited upon all the productive measures in the central parts of the area, but to have overlapped them for some distance in the southern parts, so as to rest directly upon the old Coal-measure floor along and beyond the southern margin of the region.

It can hardly be expected that the physical conditions which obtained during Coal-measure time in the Midland area were altogether quite so simple as this broad generalization would imply. Indeed, the relations of the Upper Coal-measures to the productive series in Shropshire and elsewhere seem to be incapable of interpretation, except upon the view of local elevation and erosion in inter-Carboniferous times, and there are many other difficulties which still remain to be explained. Nevertheless, for the sake of convenience of description and discussion, it may be assumed that at the close of Carboniferous time the productive Coal-measures extended in a continuous sheet over the whole of the Midland region almost to its southern borders and the non-productive Coal-measures far beyond. After the close of the Upper Coal-measure time, however, and previous to the commencement of the Trias, the basement floor of the whole of the Carboniferous region of the Midlands, together with all the sedimentary sheets which had been deposited upon it, became warped up by earth-crust move-

ments into broad arches or ridges, separated by intermediate troughs or basins. From the highest of these elevations, the Coal-measures became denuded, and in some districts the denudation progressed so far that the Coal-measures were stripped off the crests and flanks of the elevations and the pre-Coal-measure floor laid bare. In the broad hollows and basins, however, lying between the main elevations, the Coal-measures remained preserved: the thickness left being more or less in proportion to the width and depth of the basin.

To this epoch of vigorous movement and erosion succeeded the long period of slow and more or less regional depression in which the thick cover of Triassic and succeeding formations was laid down over the whole of the Midland area, over denuded elevations and undenuded basins alike.

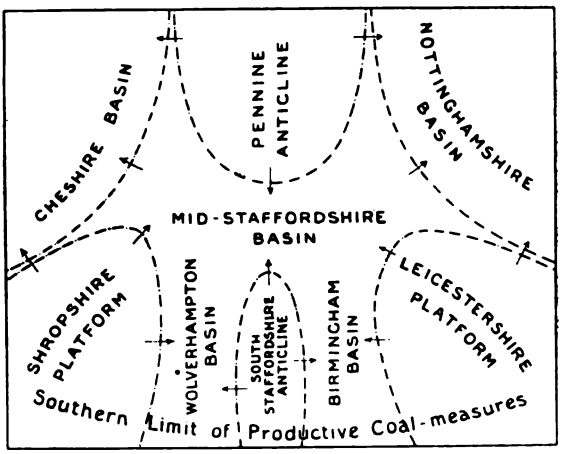

FIG. 1.—DIAGRAMMATIC PLAN OF ANTICLINES AND BASINS OF SOUTHERN MIDLANDS.

Finally came the more recent period of re-elevation and denudation, which apparently lasted from early Tertiary time down to the present, during which the red-rock cover has been again partly stripped off the country and the Coal-measures laid bare over large areas.

In order to appreciate the present distribution and relationships of the visible and hidden coal-fields of the Midlands, it is necessary to bear in mind the arrangement of the great arches and troughs into which the Carboniferous rocks and the overlying sediments have been warped.

The chief arch or anticline—the Pennine arch—enters the Midland region from the north, and comes down towards the centre of the area beyond Cheadle and Derby (fig. 1). This

arch dies down to the east into the Nottinghamshire basin, which is broad and shallow and has its outer rim in East Lincolnshire along the shores of the German ocean. The Pennine arch sinks down similarly to the west into the corresponding, but much narrower and deeper basin of Cheshire, whose outer rim lies along the high grounds of Denbigh and Flint. To the south, the great arch dips into the Mid-Staffordshire basin, which extends east and west almost from Nottingham to Cheshire.

A second but smaller arch—the South Staffordshire anticline—enters the Midlands from the south, and is prolonged northwards in its turn almost to the centre of the Midland region. This arch splits the southern parts of the Staffordshire basin into two long bays or troughs:—The Wolverhampton sub-basin and the Birmingham sub-basin. East of the Birmingham basin is the broad and irregular Leicestershire platform, which shows coal-fields emerging here and there from beneath a ragged red-rock cover, and is prolonged to the north-west below the red ground as a barren underground ridge—the Melbourne-Derby ridge—extending to the Pennine arch and separating the Staffordshire and Nottinghamshire basins. West of the Wolverhampton basin lies the corresponding Shropshire platform, which has lost practically all its former Triassic cover, and is similarly prolonged to the Pennine arch as a subterranean, but perhaps coal-bearing, ridge—the Newport-Drayton ridge—separating, along much of its course, the Staffordshire and Cheshire basins.

The visible coal-fields of Nottinghamshire, North Staffordshire, Lancashire and Cheshire flank the Pennine arch where it sinks down into the Nottinghamshire, Staffordshire and Cheshire basins. The coal-fields of Denbigh and Flint lie along the western border of the Cheshire basin, and those of Shrewsbury and Lebotwood along its border to the south. The coal-fields of Ashby-de-la-Zouch rest upon the main body of the Leicestershire platform, those of the Clee Hills on that of the platform of Shropshire, and the coal-field of Dudley on the crest of the South Staffordshire anticline. The coal-fields of Coalbrookdale and Forest of Wyre lie along the line where the Shropshire platform subsides below the Wolverhampton trough, and the coal-field of East Warwickshire where the Leicestershire platform dies down into the Birmingham basin.

The visible coal-fields of the Midlands occur, as a rule, on

the flanks of the great arches and elevations. The hidden coal-fields lie buried under the Triassic cover which overspreads the intermediate basins. Where the elevations slope very gently into the basins, as in Warwickshire and East Nottinghamshire, the prolongation of the coal-seams under the red ground can be followed, stage by stage, outwards from the visible coal-field itself. This can be done in three ways:—(1) By working the coal-seams, foot by foot, from the collieries inside the visible coal-field, deeper and deeper under the red ground. (2) By sinking trial borings in the red ground, in advance of the workings, and proving the existence of Coal-measures preparatory to sinking a shaft. Or (3) by boldly sinking a shaft in the red ground into the hidden Coal-measures below. By these three methods, employed either singly or in combination, large areas of coal-bearing ground have been won from the collective area of the hidden coal-fields of the Midlands during the last 50 years, and have been added as proved marginal coal-fields to the edges of the visible coal-fields of former days.

The total area of the visible coal-fields in the Midland region may be estimated at 1,700 square miles. The total area of the hidden Midland coal-fields already proved is about 830 square miles, equal to about one-half the area of the visible coal-fields. But this proved ground is a fraction of the collective area occupied by the hidden coal-fields of the Midlands. While it is as yet impossible, and will be so for many years to come, to calculate with any approach to accuracy the exact area; yet, if a rough estimate be made, founded upon the assumption that the profitable Coal-measures are continued under the red rocks from those points where they are found sinking down under the red ground at the edge of one visible coal-field to the point where they are found emerging at the edge of another, the collective area of the hidden coal-fields yet to be tested may be reckoned at from 5,000 to 6,000 square miles.

But this amount must be largely discounted, from the mining and commercial points of view, for there comes eventually a downward limit beyond which it becomes unprofitable to follow these hidden coal-fields in their underground extension below the Trias, no matter how promising the geologist may consider them to be as respects the number and quality of the

coal-seams that they may contain. This limit is fixed by the depth of their coal-seams below the present surface of the country. It may be true that as the depth increases the cost of extraction can be reduced by capitalists securing a larger area for working, and laying down at the commencement a plant sufficiently comprehensive to cope with the corresponding increase of output. But broadly speaking, the engineering difficulties of coal-working augment with the increase of depth or, in other words, with the thickness of the overlying cover.

At the Florence collieries of North Staffordshire, coal is worked to a depth of 3,000 feet; and at Pendleton colliery, in Lancashire, to a depth of 3,483 feet. It is not unlikely that the time is fast approaching when such mines will be worked practically to a depth of 4,000 feet; but this may be said to be the downward limit of profitable working, as accepted by mining engineers of the present day. This depth was adopted as the depth-limit by the Commissioners in the last two Royal Coal Commissions; their lead is here followed in this respect, and the limit of possibly profitable coal-working set down at a depth of 4,000 feet.

But this downward limit has a most important bearing upon the matter of the unproved hidden coal-fields of the Midlands, and at once removes at least half the area which they probably occupy from the category of practical discussion. If the Triassic rocks and the underlying non-profitable Coal-measures of the Midlands retain the same thickness in the cores of the great basins as they possess along their margins, the productive Coal-measures in the central parts of most of these basins must be well below this limiting depth of 4,000 feet.

The extension and resources of the hidden coal-fields, proved and unproved, as they are developed from district to district when followed through the Midlands, now remain to be considered.

The Pennine arch of the Northern Midlands sinks very gently downwards towards the east and south-east into the Nottinghamshire basin, which, according to the conclusions of Prof. Percy Fry Kendall, is continued eastward almost to the shore of the German Ocean before its outer border is reached, and southward, perhaps, to the latitude of the Wash. The Coal-measures

of this basin, as they sink downward in an easterly direction, are laid bare over an extent of 840 square miles, forming the visible Nottinghamshire and Yorkshire coal-field. Their continuation under the red rocks has already been proved by means of bore-holes for a distance of from 4 to 10 miles under the red ground beyond the limits of the visible coal-field, and they are already worked under the red ground by a line of shafts like those of Shireoaks, Warsop, Sherwood, etc., to a long distance outside. The total area of hidden coal-field already accepted as proved and added as a marginal coal-field to the visible coal-field is set down by Prof. Percy Fry Kendall at 570 square miles.*

But the area over which the profitable Coal-measures extend as a hidden coal-field in the Nottinghamshire basin is certainly far greater than this, and Prof. Percy Fry Kendall estimates it at 3,885 square miles.† The Royal Coal Commissioners acknowledge an area of some 2,550 square miles, extending outwards from the Nottinghamshire coal-field under the Trias and succeeding formations across Nottinghamshire and Lincolnshire almost to the edge of the Wash, and thence north-eastward to a line drawn through eastern Lincolnshire to a point midway between Selby and Hull. Throughout the whole of this area, it is possible that many of the best seams of the productive Coal-measures lie within 4,000 feet of the surface, and will be worked in the course of time. This great concealed coal-field constitutes, so far as known, the grandest hidden coal-field in the Midlands. Its Coal-measures dip at such a gentle angle, and are so little broken by faults and folds, that they can be easily worked. Some of its coal-seams, like the Barnsley Hard, have a very high reputation. Its position, lying between the large manufacturing towns of Yorkshire and Nottinghamshire on the one side and the sea on the other, has an important bearing on the demand for its coals; and its special advantages, both from the commercial and from the geological points of view, are certain to make it that hidden coal-field of the Midlands which will be most profitably and rapidly developed in the future.

West and south-west of the Pennine anticline, and thus corresponding in position to the Nottinghamshire basin, lies the great

* "Sub-report on the Concealed Portion of the Coal-field of Yorkshire, Derbyshire and Nottinghamshire," by Mr. Percy Fry Kendall, *Final Report of the Royal Commission on Coal-supplies*, 1905, part ix., page 18.

† *Ibid.*, page 32.

basin of Cheshire and South Lancashire. But, while the Nottinghamshire basin is remarkable for its shallowness, and, as a consequence, for the wide spread of workable Coal-measures, within 4,000 feet of the surface, the central parts of this Cheshire basin are of great depth, and over fully one-third of its area the profitable Coal-measures, if they exist, may lie deeper than the workable limit of 4,000 feet from the surface. The northern flanks of the basin are occupied by the visible coal-field of South Lancashire, and, under the unworked ground lying along the south of the field, the Royal Coal Commissioners estimate that some 105 square miles* have already afforded sufficient geological evidence that their Coal-meausres lie within 4,000 feet of the surface, and so this area is regarded as forming a proved extension of the Lancashire coal-field. On the western flanks of the basin, lie the Denbigh and Flintshire coal-fields, and now that the red so-called Permian measures of that country are grouped as the Keele series in the Carboniferous, much of the area that these rocks occupy is looked upon as constituting a proved marginal extension of these coal-fields. Over all the remainder of the Cheshire basin, the existence of workable Coal-measures is inferred by geologists. A broad sweep of country occupying a total area of some 200 square miles,† including the peninsula of Wirral and almost the whole of the ground intervening between the estuary of the Mersey and the edge of the Lancashire coal-field, is believed by Mr. Aubrey Strahan and others, to contain coal-seams within workable depths. Into the same category also falls a narrow strip of red-rock country on the flanks of the Lancashire-Cheshire coal-field, in the districts of Manchester and Stockport.‡ But, for all the central and southern parts of the Cheshire basin, including the whole of the country lying between Shrewsbury on the south and Runcorn on the north, Congleton on the east and Chester on the west, no estimate has yet been attempted. So far as the known geological facts enable one to judge, it would appear that in the middle parts of this great

* "Report on the Available Coal-resources of District C (North Wales, Lancashire and Cheshire)," by Prof. Edward Hull, Sir George John Armytage, Bart., and Mr. Aubrey Strahan, *Final Report of the Royal Commission on Coal-supplies*, 1905, part iv., plate i.

† "Sub-report to the Geological Committee on the Concealed and Unproved Coal-fields, not including District B," by Mr. Aubrey Strahan, *Final Report of the Royal Commission on Coal-supplies*, 1905, part ix., page 16.

‡ *Ibid.*, page 15.

area, from Middlewich through Crewe to Wem and Whitchurch, there must lie from 3,000 to 4,000 feet of Triassic rocks* upon the Carboniferous strata below. Below these, from 1,000 to 3,000 feet of Upper and non-productive Coal-measures may have to be cut through before the productive Coal-measures are reached. These numbers are, perhaps, extreme, but they are sufficient to show that under all the central parts of the Cheshire basin the profitable measures lie too deep for working.

On the eastern flanks of the basin, and between it and the North Staffordshire coal-field, runs the great red-rock fault with an unknown throw, as yet completely baffling research and enterprize in that direction. Along the southern and south-eastern margins of this basin, however, from the northern edge of the Shrewsbury coal-field far to the north-east, it is probable that Coal-measures lie under the red ground at no very great depth below the surface; such Coal-measures as are seen sinking into the basin contain, however, but a few thin coals and these probably belong to the Upper Coal-measures. It may be some miles inside the margin of the Cheshire basin in this direction before the productive measures come in, and in that distance they may have sunk to so great a depth or under such a thickness of water-bearing Trias, as to make their exploitation unprofitable.

South of the Pennine anticline, the Coal-measures sink down somewhat steeply into the Mid-Staffordshire basin. The north-eastern flanks of this basin are occupied by the strata of the visible North Staffordshire coal-field. Succeeding the grey measures of that coal-field, the band of red rocks comes in, which constitutes the Keele series, now classed as the highest member of the Upper Coal-measures. About half the width of this Keele band of North Staffordshire,† having a total area of some 10 to 12 square miles, forms a hidden coal-field, which is held to occupy ground that is already sufficiently known and is regarded as the proved extension of the Potteries coal-field. South of this proved ground lies a much broader strip of country extending from Madeley through Stone in the direction of Cheadle, occupying

* "Sub-report to the Geological Committee on the Concealed and Unproved Coal-fields, not including District B," by Mr. Aubrey Strahan, *Final Report of the Royal Commission on Coal-supplies*, 1905, part ix., page 13.

† "Report on the Available Coal-resources of District B (Staffordshire, Warwickshire, Leicestershire, Shropshire, and a small portion of South Derbyshire)," by Prof. Charles Lapworth and Mr. Arthur Sopwith, *Final Report of the Royal Commission on Coal-supplies*, 1905, part iii., page 4.

some 96 square miles* and floored partly by the Keele series and partly by the Triassic formation. In this ground it is held that, in all probability, the higher seams of the productive Coal-measures of the North Staffordshire coal-field lie within 4,000 feet of the surface. Beyond this narrow band, however, over all the more central parts of the Staffordshire basin, which are floored by the Keuper Marls, from Eccleshall almost to Burton, if the productive measures occur at all, they probably lie at unworkable depths below the surface; for, at Chartley, in the eastern part of this area, Keuper Marls have already been bored through to a depth of 2,400 feet without reaching their base,† and below this it may be naturally expected that the whole of the Bunter and some of the Upper Coal-measures might have to be pierced through before the profitable measures could be reached.

Along a line running across the eastern part of the Mid-Staffordshire basin, from Cheadle to Repton, and continued to the north-eastern parts of the Leicestershire coal-field, the basement beds of the productive measures must crop out against the overlying cover of Triassic rocks, so that a broad stretch of country forming the subterranean ridge of Derby and Melbourne, extending from this line as far eastwards as Trent Junction, must be destitute of Coal-measures.

The great Leicestershire platform extends from Burton-upon-Trent Bridge eastwards to Melton Mowbray, south and south-eastwards towards Rugby and Leicester, and westwards to Atherstone and Nuneaton. Over the whole of this platform the red-rock cover is comparatively thin, and had the Coal-measures remained as fully preserved upon this platform as in the Nottinghamshire basin, its hidden coal-fields would have been equally promising. But previous to the deposition of the Triassic cover, this area was broken up into comparatively narrow ridges, arches and folds, from the crests of which the Coal-measures were swept off and the pre-Carboniferous floor laid bare. The denuded floor shows out at the surface in Charnwood Forest, in the Nuneaton

* "Sub-report to the Geological Committee on the Concealed and Unproved Coal-fields in District B," by Prof. Charles Lapworth, *Final Report of the Royal Commission on Coal-supplies*, 1905, part ix., page 7.

† "Table and Map (plate iii.) of the more important Borings, throwing Light on the possible Occurrence of Concealed Coal-fields," by Messrs. Aubrey Strahan and O. T. Jones, *Final Report of the Royal Commission on Coal-supplies*, 1905, part ix., page 37.

district, and in the Melbourne district overlooking the valley of the Trent; it has also been met with again and again in trial-borings sunk through the red-rock cover, at Evington, near Leicester, Market Bosworth and elsewhere.* Nevertheless, the productive measures were not swept from off the whole of this platform, but are preserved more or less over its north-western parts and in certain deeper hollows to the south and south-west. They show through at the surface as the visible Leicestershire or Ashby-de-la-Zouch coal-field, and are prolonged under the red-rock cover south-eastwards as far as Desford, near Leicester, and westwards to near Donisthorpe and Overseal. Much of the Coal-measure ground under the red rocks has already been proved by borings and shafts in these directions, and largely worked for many years past. The area of hidden coal-field, thus added as an extension to the previously known coal-bearing ground, is estimated at about 54 square miles.

There are possibly other hidden coal-fields† under the red rocks of the Leicestershire platform, lying in narrow basins on the old Coal-measure floor, but such coal-seams as have already been met with in them, as near Hinckley and Brandon, are apparently thin and unprofitable.

Very different in all these respects is the ground on the south-eastern side of the Leicestershire platform, extending from Polesworth through Bedworth and Coventry in the direction of Kenilworth. Along this broad band of country, the underground platform slopes down into the eastern side of the Birmingham basin. The Coal-measures show out at the surface as the visible East Warwickshire coal-field. The main seams of this field dip, at first, steeply westwards, and then flatten out and subside gently below the broad spread of Keele or so-called Permian ground, forming a hidden coal-field of very great but unknown extent. The enterprise of the East Warwickshire mining engineers has already proved some 34 square miles of hidden coal-field under the red beds, and added it as an extension to the main Warwickshire coal-field. The new ground has been tapped in

* "Table and Map (plate iii.) of the more important Borings, throwing Light on the possible Occurrence of Concealed Coal-fields," by Messrs. Aubrey Strahan and O. T. Jones, *Final Report of the Royal Commission on Coal-supplies*, 1905, part ix., page 39, etc.

† "Sub-report to the Geological Committee on the Concealed and Unproved Coal-fields in District B," by Prof. Charles Lapworth, *Final Report of the Royal Commission on Coal-supplies*, 1905, part ix., pages 10 to 11.

colliery-workings and shafts for a distance of from 1 mile (Tunnel shaft, Newdigate colliery) to 4 miles, and the continuity of the Coal-measures under the red rocks has been shown for a distance of several miles more.* How far workable Coal-measures may extend southwards from the ground already won, the writer is, as yet, unable to say; but, judging from the manner in which the coal-seams thin away towards Wyken and Craven, it can hardly be expected that they will extend in workable thickness far south of the latitude of Coventry.

A long stretch of red-rock country occupies most of the Birmingham basin,† lying between the East Warwickshire coal-field on the east and the South Staffordshire coal-field on the west, and ranging from Henley-in-Arden on the south to some distance beyond Lichfield on the north. The prolongation of the productive Coal-measures eastwards towards the centre of this basin has been demonstrated by the extension of the East Warwickshire coal-field. The fact that they are similarly prolonged westward from the South Staffordshire coal-field has long been known; they have been mined in the collieries of Hamstead and Sandwell Park under the red ground for a distance of from at least 2 miles from the edge of the visible coal-field, and they have recently been bored into below the red ground well to the south of these localities at Langley. Several square miles of hidden coal-field have here been already tested, and partly won. There is much to be said for the view that Coal-measures extend more or less continuously under much of the red-rock ground of this Birmingham basin; but, from the commercial point of view, the several parts of the basin are by no means equally promising. It is very doubtful whether profitable Coal-measures occur south of a line drawn across the basin from Harborne to Coventry, all south of that line being occupied by upper measures. Again, over the northern parts of the basin lying between the extreme north of Cannock Chase and the Leicestershire coal-field, the geological evidence goes to show that rocks older than Coal-measures crop out in that direction under the cover of

* "Report on the Available Coal-resources of District B (Staffordshire, Warwickshire, Leicestershire, Shropshire, and a small portion of South Derbyshire)," by Prof. Charles Lapworth and Mr. Arthur Sopwith, *Final Report of the Royal Commission on Coal-supplies*, 1905, part iii., pages 5 to 6.

† *Ibid.*, part iii., pages 5 to 6; and "Sub-report to the Geological Committee on the Concealed and Unproved Coal-fields in District B," by Prof. Charles Lapworth, *Final Report of the Royal Commission on Coal-supplies*, 1905, part ix., pages 9 to 10.

the New Red rocks. If coal-seams are present, the measures will probably be found to dip and thicken towards the Lichfield country.

The productive measures are perhaps in their greatest force along a line drawn across the basin from Aldridge towards Tamworth; but they probably lie at comparatively great depths, for the highest member of the non-productive series—the Keele or so-called Permian—is mapped as showing at the surface at more than one locality, as near Four Oaks, and in a recent boring at Streetly its thickness was found to be great. Promising as this ground appears to be from the geological point of view, the great but unknown throw of the western boundary fault on the one side and the Tamworth faults on the other have hitherto acted as effectual deterrents to mining speculation in this country.

West of the Birmingham basin runs the long and narrow South Staffordshire anticline and its visible coal-field.* From the crest of this arch, over an extent of some 105 square miles, the red-rock cover has been removed, laying bare the underlying Coal-measures and giving origin to the visible South Staffordshire coal-field. West of the visible coal-field lies the Wolverhampton basin, answering in its way to the Birmingham basin on the opposite side. Eastward, the coal-field is limited by the eastern boundary fault, and westward by the corresponding western boundary fault, both of very great throw. Southward, the arch dies down under the red rocks of the Lickey Hills, while northward it is prolonged far under the red rocks of Cannock Chase. To the south there is no hope of the discovery of a hidden coal-field, for the sinkings of Manor pit and Wassel Grove show that the profitable Lower Coal-measures thin out or deteriorate in this direction. Northward, however, the coal-seams are prolonged far under the red-rock cover in the direction of Stafford. The enterprise of South Staffordshire mining engineers has already proved a hidden coal-field under the Cannock Chase country by workings, shafts and borings to a distance of from 1 to 3 miles in a north-westerly direction; and the thickness of the profitable measures and the collective thickness of the coal-

* "Report on the Available Coal-resources of District B (Staffordshire, Warwickshire, Leicestershire, Shropshire, and a small portion of South Derbyshire)," by Prof. Charles Lapworth and Mr. Arthur Sopwith, *Final Report of the Royal Commission on Coal-supplies*, 1905, part iii., pages 4 to 5.

seams appear both to increase in this direction, while, as yet, the red-rock cover has only thickened to a few hundreds of feet. It is not impossible that, for many miles beyond this, the workable measures will be found to lie within a reasonable depth of the surface. The beds, however, in the more northerly parts of the Cannock coal-field, dip to the west and south-west, so that on the north-east side fewer and fewer seams come in below the red-rock cover; and such evidence as has been obtained during the last few years goes to show that on the north-eastern side of the Cannock Chase country the base of the Coal-measures may be eventually reached.

Immediately west of the coal-field, and cutting it off from the Wolverhampton basin, comes the western boundary fault, bringing the red rocks suddenly against the Coal-measures of the visible coal-field. Until quite recently, the great but unknown throw of this fault effectually barred all coal-mining enterprise beyond it. But within the last twenty years, the advance of geological knowledge on the one hand, and the certainty of the approaching exhaustion of the coal-seams in the visible coal-field on the other, have together prompted the more sanguine members of the coal-mining community of South Staffordshire to risk the venture of proving the hidden coal-fields, which should theoretically lie beyond it in a westerly direction. In the only two instances in which this venture has been attempted, it has met with success. The presence of Coal-measures outside the western boundary fault under the Triassic rocks of the Wolverhampton basin* has been shown at the borings of Four Ashes and of Baggeridge. At Baggeridge, the proof has since been utilized by the sinking of shafts preparatory to the commencement of colliery-workings. The total area of hidden coal-field thus tested outside the western boundary fault may be roughly set down as 10 square miles. Yet this is but a narrow strip along the eastern edge of the great Wolverhampton basin. The extent of red-rock country occupied by the basin is some 20 miles long, from the latitude of Stafford on the north to that of Kidderminster on the south, and some 12 miles wide, from the

* "Report on the Available Coal-resources of District B (Staffordshire, Warwickshire, Leicestershire, Shropshire, and a small portion of South Derbyshire)," by Prof. Charles Lapworth and Mr. Arthur Sopwith, *Final Report of the Royal Commission on Coal-supplies*, 1905, part iii., page 5; and "Sub-report to the Geological Committee on the Concealed and Unproved Coal-fields in District B," by Prof. Charles Lapworth, *ibid.*, part ix., pages 7 to 8.

boundary fault on the east to the coal-fields of Coalbrookdale and the Forest of Wyre on the west. A thickness of from 1,100 to 2,100 feet of Upper Coal-measures shows out along the margin of the basin above the productive coal-seams; and farther inwards this is followed by a thickness of 1,300 to 1,400 feet of Triassic sandstones. In the central parts of the basin, this sandstone is overlain by an unknown but great thickness of Keuper Marl. It follows, therefore, almost of necessity, that over the more central part of the basin where the Marls show at the surface, as in the country running north from Patshull to Ecclesshall, the productive Coal-measures may lie at a depth of from 3,000 to more than 4,000 feet from the surface.

Between these more central areas, however, and the margins of the basin, if the productive measures are present they will lie at more reasonable depths. They are worked already on the western margin of the basin from the collieries inside the coal-field of Coalbrookdale, at Madeley and Oakgates, for some distance under the so-called Permian or Keele rocks; and the whole extent of this Keele country, extending almost to the town of Shifnal, is regarded as constituting a hidden coal-field already practically proved. But throughout the red-rock ground, forming the remainder of the western and southern sides of the basin, only one enterprising venture has yet been made. This is the boring at Claverley recently completed. It may reasonably be expected that, under the red-rock country, lying between this point and the Staffordshire coal-field in the one direction, and the Coalbrookdale coal-field in the other, the productive Coal-measures soon occur in force and in workable condition.

To the south, south-east, south-west and west, matters are very different. The whole of the Forest of Wyre coal-field, forming the south-western flank of the Wolverhampton basin, appears to be occupied at the surface by the upper and non-productive Coal-measures. Only in one small area in the Forest of Wyre coal-field, namely, in the district of Highley, near Kinlet, are the productive or sweet coals known to occur below the Upper Coal-measures* nor, as matters stand, can these sweet

* "Sub-report to the Geological Committee on the Concealed and Unproved Coal-fields in District B," by Prof. Charles Lapworth, *Final Report of the Royal Commission on Coal-supplies*, 1905, part ix., page 7.

coals be expected in force below much of the red ground of the Enville country. Down the valley of the Stour, however, between Tettenhall and Stourbridge, they may occur in workable thickness; but, if so, they are certainly covered by a great thickness of water-bearing rocks. Under the New Red Sandstone from Shifnal to the latitude of Bridgnorth, they may be expected to prove fairly well developed under the Triassic beds within a reasonable depth of the surface. But there is the same difficulty in that ground as under the Stourbridge country, for there is a great thickness of water-bearing rocks to be cut through and tubbed out before it would be possible to work them.

On the Shropshire platform,* which occupies all the country lying between the Wolverhampton basin and the Welsh mountain border, only thin coal-seams, apparently belonging to the Upper Coal-measures, are as yet known to occur. This is the case both in the Lebotwood and the Shrewsbury coal-fields, and this fact will no doubt have a very restrictive effect upon the search for coal under the red ground which lies to the north of them and sinks towards the depths of the Cheshire basin.

There can be little doubt that, a few miles north of these coal-fields, the productive Coal-measures occur below the Upper Coal-measures; but, as they make their appearance, the Triassic beds, probably rich in water, also come in above them, and thus add to the cost of the sinking. There is, however, one band of country, namely, that joining the Shrewsbury and North Staffordshire coal-fields, some of which looks fairly promising. The Keele beds of the Upper Coal-measures are mapped as showing out along this band at the surface, as at Child's Ercal, Plaswarden, and other localities, and it might be inferred that the productive Coal-measures occur within workable depths below. But here, it must be remembered that on the Shropshire side of this band there are no productive Coal-measures whatever below the Upper Coal-measures, while on the North Staffordshire side there occur some 2,000 feet of non-productive Coal-measures before the productive Coal-measures are reached, and even this great thickness does not show the top of the barren series. Any boring, therefore, made along this line must, in the meantime, be looked upon as almost wholly speculative.

* "Sub-report to the Geological Committee on the Concealed and Unproved Coal-fields in District B," by Prof. Charles Lapworth, *Final Report of the Royal Commission on Coal-supplies*, 1905, part ix., pages 11 to 12.

It is quite impossible, of course, to make more than the roughest estimate of the extent or the value of the workable coal-seams in the hidden coal-fields of the Midlands. In spite of all that has already been discovered it may be regarded as certain that no two independent investigators would arrive at precisely the same conclusions either as respects the true limits of the Midland region or the distances to which its individual seams are prolonged in a workable thickness or condition. But if, for the moment, the boundaries here suggested be accepted, the area once occupied by the productive Coal-measures may be estimated at about 11,000 square miles. From this, some 3,000 square miles of Coal-measures have been denuded away, leaving some 8,000 square miles of country where they may still remain preserved. About 1,700 square miles only are exposed in the visible coal-fields, leaving 6,000 square miles as the total extent of country possibly occupied by the hidden coal-fields of the Midlands.

Judging from the reports of the Royal Commission on Coal-supplies, only an extent of some 800 square miles or thereabouts of the hidden coal-bearing area of the Midlands has hitherto been tested by coal-workings or by borings, and all the rest has yet to be proved. Throughout much of this remainder the coal must lie at greater depths than 4,000 feet. But, if the conclusions of the geologists, who assisted in drawing up the reports, are well founded, more than 3,000 square miles of hidden coal-field lie as yet untested at less than 4,000 feet from the surface. It cannot reasonably be hoped that very much of this untested ground will be entered upon for many years to come, and in estimating the promise which it holds out it must not be forgotten that, with every increase of depth the working becomes more difficult and more costly. It cannot be safely presumed that from all the hidden coal-fields, yet to be tested, the miner can expect to secure an available mineral wealth per square mile proportionate to that of the coal-fields already proved.

It is well to be assured that in all likelihood the collective area of unproved hidden coal-fields of the Midlands, in which coal lies within a possible working depth from the surface, is larger than the collective area of the visible and proved coal-fields combined. But it will be a great misfortune if this assurance prompts to hasty experiment or rash speculation. The complications are so many that mining engineers cannot be too cautious. Geologi-

cal researchers must be taught to carry on their work into all branches of the subject and down to the most accurate details. Mining engineers must be trained to ever higher skill to face the growing difficulties. No speculative sinking should be started until the scientific and the practical evidence has been fully gone into, and the commercial promise of the venture has been carefully weighed against the certainty of the pecuniary risk.

The PRESIDENT (Mr. F. A. Grayston), in moving a vote of thanks to Prof. Lapworth for his valuable paper, said he hoped that the concluding remarks with regard to proving the hidden coal-fields of the Midlands would be of benefit to the experienced mining engineer and to the student also. Perhaps some of those present might have an opportunity in the course of their career of putting into practice the valuable advice given by Prof. Lapworth.

Mr. G. H. CLAUGHTON, in seconding the vote of thanks, said that it was in accordance with Dr. Lapworth's advice that the successful sinkings at Baggeridge were in their present position; and those interested would ever be grateful to him for his help and co-operation. They were very fortunate in possessing a man of his great ability and the ready access to his great knowledge. He trusted he would long be spared to them.

Mr. ALEXANDER SMITH asked whether, as suggested by Sir Roderick Murchison and Prof. Hull, the old rocks might intrude in part of the Birmingham basin, and whether these older rocks were struck at the Sandwell Park new sinking.

Mr. W. F. CLARK remarked that he had had occasion to get the valuable assistance of Prof. Lapworth for boring through the red rocks in the Cannock Chase district, where coal was eventually proved, exactly as Prof. Lapworth had feared it would be, that was, at such an angle that it could not be profitably worked.

Mr. HENRY JOHNSON wrote that the subject treated by Prof. Lapworth was of great importance to the Midlands and to

Birmingham in particular. He suggested, as touching the economic part of the subject, that as the future mining of this country must be at increased depths, greatly increased working-areas would be requisite to warrant the very large capital-cost of the future collieries; and consequently that the working-areas should not be broken by a large number of small ownerships of the minerals. It would, therefore, be well for the Government, in dealing with any proposal for the subdivision of the lands into small ownerships, to have a care for the future mining of the country, by not hampering it by subdivision of the mines as well as of the lands.

THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,
HELD IN THE TECHNICAL COLLEGE, GLASGOW, FEBRUARY 13TH, 1907.

DR. ROBERT THOMAS MOORE, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read ar confirmed.

Office-bearers for the session 1907-1908 were nominated, ar Auditors were appointed to examine the Treasurer's accoun for the past year.

The following gentlemen, who had been duly nominate were elected:—

MEMBERS—

Mr. JOHN BLACK BOYD, P.O. Box 262, Johannesburg, Transvaal.
Mr. THOMAS R. GILLESPIE, Blantyre Collieries, Blantyre.
Mr. KIRKWOOD HEWAT M'NEILL, Island View, Ballycastle, County Antrir
Mr. THOMAS SMITH, Fernbank House, Kelty.

ASSOCIATE MEMBERS—

Mr. WILLIAM KYLE, Winchburgh.
Mr. ADAM MURDOCH, Backus and Johnston Company, Casapalca, Peru.

DISCUSSION OF MR. GEORGE NESS'S PAPER O "EFFECTS OF ACCELERATION ON WINDIN TORQUES, AND TEST OF TARBRAX ELECTRIC WINDING-PLANT."*

Mr. T. LINDSAY GALLOWAY (Glasgow) said that the membe were very much indebted to Mr. Ness for placing before the definite facts as to the amount of current consumed by th winding-plant, which was the first electrical winding-plant

* *Trans. Inst. M. E.*, 1906, vol. xxxii., page 287.

Scotland. It would be observed that the test lasted for a little over 2 hours, and during that time, 117 winds were made, the useful load being 12½ cwts. Mr. James Caldwell stated that the useful load for which the plant was designed was about 25 cwts.* He thought, therefore, that it might be interesting to know why the tests were made with a load of 12½ instead of 25 cwts., as it was remarked by Mr. Ness in his paper that that circumstance was unfavourable to the testing of the plant. He observed, further, that the power-consumption, at the switchboard, was 0·541 unit per wind;† and they were also told that the consumption of direct current as between the motor-converter or flywheel motor and the winder was 0·2603 unit per wind.‡ He wanted to know whether he was correct in assuming that the actual consumption of power as delivered from the main was 0·541 unit per wind, and that 0·2603 unit was the consumption of direct current as between the motor-converter and the winding-engine. Mr. Ness remarked that the latter figure represented an efficiency of 48¼ per cent., but if they compared the useful work in lifting shale with the power taken at the switchboard, the efficiency was only 41 per cent. He thought that most steam winding-engines, with a mechanical counterbalance, would show at least as high a result. Of course, they had to bear in mind that the plant was not working at its full capacity, and when that happened they could not expect to get the same efficiency from it as when it was working at full power. The members had not been informed as to the first cost of this plant, but Mr. Ness had supplied an estimate of the cost of a similar installation, amounting to £5,633 or, omitting the duplication of certain parts, to £4,633. This amount would, he thought, be regarded as a most liberal estimate for a steam winding-plant capable of drawing 650 tons from a depth of 420 feet. When all the circumstances were considered, the members might ask themselves whether the use of electricity for winding was advisable and worth such an expenditure. The point had often been raised by members that, if they had to apply a steam-engine to create electricity and then utilize that electricity for winding, they ought rather to employ the engine direct and wind with steam instead of utilizing electricity. In the

* *Trans. Inst. M. E.*, 1906, vol. xxxi., page 227.

† *Ibid.*, 1906, vol. xxxii., page 290. ‡ *Ibid.*, 1906, vol. xxxii., page 291.

case of oil-works, where, if he was rightly informed, there was a large quantity of waste heat, which could be utilized for the production of electricity, it seemed economical to utilize it for that purpose. Power-supply companies were being established all over the country, and the day might come when collieries, instead of creating their own power, would take it from the general supply-mains. In that event, they would have to face the question of electrical winding. Consideration must, he thought, be paid to the possibility of reciprocating winding-engines becoming obsolete. Steam-turbines had been found to be much better suited for generating electricity, when the size was sufficiently large, than reciprocating engines. Looming in the near distance, they had the suction-gas engine. If either of these types of engine came to be adopted at collieries, they would probably entail electrical winding. Personally, he thought that they had not seen the last of this subject, and it was one which the members ought to keep before them.

The PRESIDENT (Dr. Moore) asked whether Mr. Ness could state the proportion that the work done in lifting 650 tons of shale, from a depth of 420 feet, bore to the amount of power generated in the cylinders of the steam-engine.

Mr. GEORGE NESS said that Mr. Caldwell had stated that the plant had been made for an output of 25 cwts. per wind; and it was the case that the test which he had described in his (Mr. Ness's) paper had been made with an output of only half that amount. He was not able to enter into the exact reasons governing this circumstance further than this, that when the test was made the plant had to be taken off the contractor's hands; and, owing to various causes, the test was made at a period when the full output could not be obtained from the mine. The number of units delivered at the switchboard was 0·541 per wind; and this was employed in transforming the current from three-phase alternating to continuous current in the flywheel converter. The total current of 0·2603 unit per wind, sent from the flywheel motor-dynamo into the motor, wound the cages; and it was quite independent of the current taken to excite the fields of the winding-motor, which was included in the total of 0·541 unit.

A large amount of energy was lost by the friction of the

flywheel in the air. A plant was running at the Clydebank Dock, belonging to the Clyde Trust, where the same principle was in operation. There was, however, this exception that there was more than one winding motor getting power from the flywheel converter, the flywheel was run in a vacuum, and the shaft was carried on roller-bearings.

The stated efficiency of ($100 \times 0{\cdot}2603 \div 0{\cdot}541$ or) 48¼ per cent. was the calculated efficiency of the electrical plant under the conditions existing during the test, but he (Mr. Ness) was of opinion that the total efficiency considered in terms of shale lifted, compared with the total energy put into the system, would be about 47 per cent.

The total energy employed in lifting 12½ cwts. to a height of 420 feet in 25 seconds would be $[(12\frac{1}{2} \times 112 \times 420) \div (550 \times 25) =]$ 42·76 horsepower. The consumption of 0·2603 unit per wind was equal to $[(0{\cdot}2603 \times 1{,}000 \times 60 \times 60) \div (25 \times 746) =]$ 50·24 horsepower. The efficiency, in terms of the energy put into the armature of the winding motor, was, therefore, $(100 \times 42{\cdot}76 \div 50{\cdot}24 =)$ 85·11 per cent.

Referring now to the current delivered at the switchboard, the total energy put into the system was 0·541 unit. Now, the number of winds was 117 in a period of 140 minutes, or at the average rate of one wind in 71·8 seconds. This point would be referred to later, as there was no intention to cloud the issue as to the useful efficiency in any way, and in the meantime, 0·541 unit would be taken as consumed during the actual period of the wind of 25 seconds. A consumption of 0·541 unit in 25 seconds represented a total energy of 104·28 horsepower, and the useful efficiency was $(100 \times 42{\cdot}76 \div 104{\cdot}28 =)$ 41 per cent. as stated by Mr. Galloway.

How then was this 41 per cent. to be reconciled with the former statement that the whole efficiency was about 47¼* per cent? It would be remembered that the plant was designed to make a wind every 55 seconds. Owing to the development of the mine at the time of the test, allowing of a load of only half the estimated amount, namely, 12½ cwts. per 71·8 seconds, instead of 25 cwts. per 55 seconds, the time taken for decking purposes was 46·8 seconds instead of 30 seconds. This necessitated the flywheel converter and auxiliary plant running an

* *Trans. Inst. M. E.*, 1906, vol. xxxii., page 105.

additional period of 16·8 seconds between the winds. The difference between the unit (0·2603) consumed in actual winding, and the unit (0·541) at the switchboard, represented the losses due to friction, heating and field-excitation during the period when the plant was not performing useful work. This difference, amounting to 0·2807 unit, spread over 71·8 seconds, gave, over one second, a power-consumption of (0·2807 ÷ 71·8 =) 0·0039 unit. He had previously stated that the observed power-consumption, when the winder was at rest, was 15 kilowatts,* and this, divided by 3,600 seconds, gave a consumption of 0·0041 unit over 1 second or an observation-difference of 0·02 per cent. If the lesser figure, 0·039 unit, were accepted as correct, it might be assumed that the plant was penalized, by the prolonged decking period of 16·8 seconds above that estimated, to the extent of (0·0039 unit × 16·8 =) 0·06552 unit. Substracting this amount from the 0·541 unit delivered at the switchboard, the total units which would have been delivered to the plant, if the estimated period for decking purposes of 30 seconds had been adhered to, were 0·47548 unit, giving an electrical efficiency of (100 × 0·2603 ÷ 0·47548 =) 54·74 per cent. Again, taking 0·47548 unit as consumed during the winding period of 25 seconds, representing a total energy of 91·59 horsepower, the useful efficiency was (100 × 42·76 ÷ 91·59 =) 46·7 per cent.

It might be shown by a *reductio ad absurdum*, that this reasoning was based on absolutely fair lines, without prejudice either in favour of or against this system of electrical winding. Supposing a wind to be made, after which the flywheel converter continued to run on for 2 hours before the next wind took place. The consumption by observation to run the flywheel converter idle was at the rate of 15 units per hour, and would, therefore, for 2 hours, be 30 units + 0·47548 unit taken in winding. If this were considered from the point of view of useful work in lifting shale, there would be a total consumption in the 25 seconds' period of winding of 30·47548 units, or energy at the rate of 1·219 units per second, or 5,882 horsepower: and the useful efficiency would be (100 × 42·76 ÷ 5,882 =) 0·7 per cent., a result which was sufficiently absurd to prove that losses due to time occupied in decking operations should not be debited against the plant in estimating its efficiency.

* *Trans. Inst. M. E.*, 1906, vol. xxxii., page 291.

One of the chief features in this installation was that, with a maximum energy of 45 kilowatts delivered into the system, and that only over a short period of time, a peak-load of 104 kilowatts* was obtained in the winder during the test.

With reference to the useful efficiency in winding shale, compared with the work done in the cylinders of the engine: the engine was situated about ¾ mile from the mine at which the winding installation was situated. Diagrams were not taken at the time of the test, and, if they had been, they would have been useless, as power was delivered throughout a considerable area for other purposes, and thus there would always have been considerable doubt as to the proportions of power being taken by the different processes, more especially as the load was a variable one. It was perfectly safe, however, to assume an efficiency of 80 per cent. for the conversion from mechanical to electrical energy, including the loss in the cables; and, taking the useful efficiency or power delivered at the switchboard as 46·7 per cent., then the total useful efficiency in lifting shale would be $(46{\cdot}7 \times 80 \div 100 =)$ 37·36 per cent. If this figure were taken, it should be pointed out in all fairness that the result was very much in favour of the winding-plant, as it comprized a high-class engine and boiler-installation, which, on calculation from tests, would give 1 kilowatt for a consumption of 4 pounds of coal. Allowing, say, 10 per cent. for the increase of energy necessary to deliver this unit at the switchboard, this worked out at 4·4 pounds of coal per unit delivered at the winding-house. The total consumption per ton on the basis of the trials, without deduction for decking-time losses, was shown to be 0·866 unit per ton,† or $(4{\cdot}4 \times 0{\cdot}866 =)$ 3·8 pounds of coal consumed per ton of shale raised. In compiling his previous estimate for comparative purposes, it should be noted that he (Mr. Ness) took 4 pounds of coal per unit,‡ but he had employed it per ton, as the difference was so trifling. A fuel-consumption of 4 pounds per kilowatt-hour, or 3 pounds per horsepower-hour, in mining operations was certainly a moderate figure compared with the figures given by their past-President (Dr. J. S. Dixon) in his "Presidential Address." The result of a test of all the engines at a modern well-equipped colliery showed that the average

* *Trans. Inst. M. E.*, 1906, vol. xxxii., page 292, plate xiii., fig. 3.

† *Ibid.*, 1906, vol. xxxii., page 291. ‡ *Ibid.*, page 292.

fuel-consumption was 8·21 pounds of coal per horsepower-hour, and in the case of two winding-engines 9·87 pounds of coal per horsepower-hour.*

The result of the test of the Tarbrax plant afforded a striking example of what could be effected by the concentration of power in, and transmission from, a central generating-station.

The discussion was thereupon closed, and a hearty vote of thanks was awarded to Mr. Ness.

DISCUSSION OF MR. JOHN B. THOMSON'S PAPER ON "TESTS OF A MINE-FAN."†

Mr. Thomas Turner (Kilmarnock) wrote that the particular Capell fan was built for a duty of 50,000 cubic feet of air per minute at a water-guage of 2 inches, on the usual condition, namely that the mine would yield that quantity at that gauge: the speed of the fan to be about 230 revolutions per minute, and the efficiency of the combined fan and engine approaching, say, 70 per cent. Tests made by the owners showed 60,000 to 64,000 cubic feet per minute passing through the drift, at a water-gauge of 2 inches to 2½ inches, and the makers were not, therefore, required to perform any tests. Subsequent tests carried out in the fan-drift showed roughly 20 per cent. more duty than was shown down the pit; but, even when that 20 per cent. was deducted from the above-given figures, the fan was evidently right for its work. He (Mr. Turner) did not expect quite so much as 86 or 87 per cent. of duty out of the installation, and he thought that the high figures were due to the testers not finding out all the negative or reverse currents of the eddies. To get these more accurately it might be necessary to divide the drift into 18 or 36, instead of 9 spaces. Anemometer-readings, however, should, if possible, be taken at a place where there were no eddies, that was to say, at a place where there was a steady flow of air in one direction over the whole area measured. In this respect, the measurements down the pit were better than those in the drift, the latter being too short to allow the air to become steadied down to a regular flow in one

* *Trans. Inst. M. E.*, 1902, vol. xxiii., page 373.

† *Ibid.*, 1906, vol. xxxii., page 295.

direction only in its length. The measurements down the pit might, however, not include all the air that passed through the fan. He asked whether there was a possibility of air or gases being drawn from the unworked seams at the bottom of the upcast shaft.

Mr. H. D. D. BARMAN (Glasgow) considered that it would be difficult to make accurate tests of this fan, as it must be admitted that Mr. Thomson had a very awkward shaft to work in. The tests would undoubtedly be influenced by the air having to turn round a sharp corner from the vertical shaft to the fan-drift. If Mr. Thomson could find time to erect shutters and to make tests with the drift entirely closed, and then with apertures of 4, 9, 16 and 25 square feet, he would thus get a characteristic curve which would show that his former tests with the full apertures were inaccurate.

Prof. A. RATEAU (Paris) wrote that the recorded experiments gave a combined result for the fan and engine nearly equal to the efficiency expected for an engine alone. This surprising result could only be based upon errors in the methods of measurement; and, from the records of the results of the experiments, it was easy to recognize that the measurements of the volume of air and the measurements of the water-gauge both yielded exaggerated figures. One could well, in this way, find an efficiency superior to unity, as had been done in other tests. One could not take too many precautions in making experiments on the efficiency of fans. The volume of air had been measured in the delivery-passage to the fan, immediately after an abrupt bend that conduced to throw the current of air to the upper part of the fan-drift, to such an extent that the current returned on itself in the lower part of the drift. In such conditions, the measurement of the volume by an anemometer would certainly yield results much greater than the reality. It was wellknown that anemometers always showed exaggerated results, and especially when the current in which they were placed was very irregular. The members might consult in this respect his (Prof. Rateau's) experimental work.*

* "Experimental Investigations upon the Theory of the Pitot Tube and the Woltmann Mill," by Prof. A. Rateau, *Trans. Inst. M. E.*, 1899, vol. xvii., page 124.

The fourth experiment, made on November 14th, 1905, in which the air was measured at the pit-bottom and simultaneously near the fan, showed well the exaggerated volume: near the fan, the anemometers showed a delivery of 37·5 per cent. better than that at the bottom of the pit. Unquestionably, the volume near to the fan was really greater than the delivery at the bottom of the pit, (1) because the atmospheric pressure was rather less, and (2) there was probably a re-entrance of air at the interstices of the door that closed the upper part of the pit. But these causes of increased volume were certainly far from accounting for the 37·5 per cent. shown by the anemometers.

Regarding the water-gauge, it had been mentioned that this was measured in the fan-drift at the point where the current of air had a very high velocity, attaining and even exceeding 4,000 feet per minute. This measurement had probably been made with a straight tube, whereas it should have been made with a Pitot tube, turned towards the current. In the measurement with the straight tube, account had not been taken of the energy (due to the actual velocity) that the current of air possessed in the passage, energy which assisted the fan. A velocity of 4,000 feet per minute was equal to a supplementary water-gauge of 1 inch; and this was enormous when compared with the measured water-gauge of 2¼ inches.

Besides the effect of the velocity of the air-current, it must be remembered also that the measurement by a straight tube indicated a figure less than that which corresponded to the static pressure at the point of observation. For these reasons, it was probable that the pressure measured was about 40 per cent. higher than the true water-gauge. Consequently, he (Prof. Rateau) was of opinion that the tests had been made in a manner which did not allow of an exact measurement of the efficiency of this fan. In order to obtain more exact results, it would be necessary to measure the volume in a drift, where the air-current was regular in all sections of the drift, and to measure the water-gauge in the drift in front of the fan at a point where the current had not a high velocity, and a correction corresponding to the velocity should be applied, a correction that was recorded when the measurement was made with a Pitot tube.

Mr. T. Lindsay Galloway (Glasgow) said that he did not think that a test could be considered sufficiently conclusive when

there was a difference of 30 per cent. in two measurements of the volume. He asked whether the anemometers had been tested at high velocities, such as 60 feet per second. He did not know whether any better method, than that in operation in the mine, had been devised for producing high velocities. Perhaps some member could enlighten him on that point. He suggested as a subject for enquiry whether reliance could be placed on anemometers at high velocities, and what means were adopted for testing them. In any case, a reliable instrument would probably not give correct indications in an unsteady current, full of eddies, such as were produced in a short fan-drift.

Mr. T. H. MOTTRAM (Glasgow) asked why the anemometers registered a greater velocity in the fan-drift than was due to the quantity of air actually passing. He would like to know whether the fan-drift, in which the air was measured, was level, if the fan was directly in the centre, and how near to the fan Mr. Thomson's measurements were taken. He noticed that the highest velocities were got at the top of the drift, and the negative ones at the bottom. This indicated that the main portion of the air-current was passing from the bottom of the drift at the shaft to the top of the drift at the fan. He would also like to know whether the high velocities referred to were still maintained at the top of the drift when the false floor of wood and brattice-cloth was in use. When an open light was held well to the side of an air-current passing through an air-regulator it became unsteady, and in some cases indicated a kind of whirl: and, if this experiment could be applied to the air in a fan-drift, a similar result would probably be obtained, as the rebound and meeting of the currents at an angle would produce a whirl in the air in close proximity to the fan. He imagined, where the area of a fan-drift was considerably larger than the area of the ear of the fan, that the whirl would be intensified—the air to some extent moving round a centre, and consequently an anemometer would record misleading results. Mr. Thomson had referred to the *vena contracta*, or, as it is sometimes termed, the co-efficient of contraction of the area of a jet escaping from an orifice. The *vena contracta* is generally reckoned at 0·65 times the area of the opening in a thin plate, but this may vary according to the construction of the fan. The application of this co-

efficient to a quantity of 58,000 cubic feet would yield about 43,000 cubic feet, approaching the actual quantity passing through the drift in the Ell coal-seam. At the same time, that application must not be considered as a reliable method of arriving at the quantity of air actually passing. A simple experiment would show how unreliable measurements of air might be, when taken in close proximity to a fan. For instance, small pieces of paper, discharged into the current under some conditions, would indicate a whirl in the air. He had seen, while most of the pieces of paper made direct for the fan, that others whirled round and round before entering it. There could, he thought, be no doubt about the matter, and he agreed with Mr. Thomson that, in testing a fan for its mechanical efficiency, the measurements of the quantity of air should not be taken in the fan-drift —at any rate not in a drift so short as the one in which his experiments were taken.

Mr. Sam Mavor (Glasgow) said that the observations of wind-pressure made by the engineers of the Forth Bridge, extending over a period of seven years, elicited some points of interest in relation to the behaviour of air-currents. Wind-gauges of different sizes were used, varying from 1 or 2 square feet, to 300 square feet in area, and it was found, during wind-storms, that the gauges of small area registered much higher pressures than the mean pressures on those of large area. The tests showed, even with gauges placed in the open atmosphere, high and free from disturbing environment, that the pressure on the surface (of a gauge with an area of 300 square feet) differed at different parts of the surface, and that the points of highest pressure changed from moment to moment, with a relatively small variation of the total mean pressure. The occurrence of such differences in the open atmosphere indicated the probability that similar fluctuations would occur in the roadways of a mine, and that they would be emphasized by the proximity and irregularity of the walls, floor and roof.

Mr. J. M. Ronaldson (Glasgow) said that he found by experience, many years ago, that the more slowly the air was travelling the more likely was it that he would secure accurate readings from the anemometer. He found that he could never really make a proper test when the air was moving at a great velocity in the

fan-drift. He always preferred to take readings of the anemometer of the various splits of air belowground, as a proper index of the amount of air passing through the mine, in preference to taking a reading in the fan-drift where the air was probably travelling at a great velocity, and the whirls were apt to disconcert the reading of the anemometer. In dealing with whirling currents, it was most difficult for any anemometer to register correctly the exact average velocity of the air. Therefore, he thought that experiments should only be attempted under circumstances where the air was not travelling at too high a velocity, and in a straight part of the airway where the area did not greatly vary.

Mr. R. W. Dron (Glasgow) said that recently he had had an experience similar to that recorded by Mr. Thomson, although he had not found time to go into the details in the same scientific way as that gentleman had done. The anemometer indicated about 60,000 cubic feet of air per minute in the fan-drift, but the actual quantity of air circulating underground was only about 40,000 cubic feet per minute. In his own mind, he was satisfied that the actual quantity was 40,000 cubic feet. The reading of the anemometer in the fan-drift, in his case, had been probably effected in the same way as in Mr. Thomson's tests.

Mr. James Black (Airdrie) said that Mr. Thomson was perfectly right in regard to the method that he had adopted for calculating the efficiency of the fan. The work done on the negative currents was not the same as the work done on the positive currents, because, comparatively speaking, no work was done on the negative currents, and they were not circulated against the resistance of the mine like the positive currents. Mr. Thomson seemed to have been mystified at obtaining such widely different results; and if he had obtained the same efficiency in his series of experiments, he (Mr. Black) would have been just as much surprised as Mr. Thomson had been. The members should consider the fact that the ear of the fan was only 18 feet from the edge of the shaft, and the air passed round a right-angled turn, setting up cross currents; and under such conditions, he was not surprised that the anemometer failed to record correct measurements, but indicated the velocity of the oblique currents. Mr. Thomson's results showed that negative currents flowed upon the floor of the fan-drift, and that the

highest velocities existed near the roof. The highest veloc
could have been measured in the centre of the fan-drift,
the velocity of the air-current, over the entire sectional ar
had been at right angles to the cross-section of the airwa
In his opinion, it was simply the length of the fan-drift th
determined the extent to which the measurements of the veloc
might be affected by cross currents. If the fan-drift had be
sufficiently long to give the air-current time to get into
normal course, then it would have made no difference wheth
the air was measured in the fan-drift or at the pit-bottom,
far as accuracy of measurement at the respective points w
concerned. A simple example of the effects of cross curren
could be seen in any fast-running stream of water, where it ma
a right-angled bend; and negative currents could also
observed in many of such cases.

He (Mr. Black) did not agree with the mode adopted
Mr. Thomson when measuring the ventilating-current. T
nine spaces, into which the fan-drift was divided, had an avera
area of about 4 square feet, and consequently were much t
large. The area of each space should have been restricted
about 2 square feet, in order that more accurate results mig
be obtained. He also objected to the method of fixin
the anemometers on shelves, placed across the fan-drift, as th
air, in passing through the divisions formed by the shelve
was affected in the same way as air was affected in passin
through a regulator. The shelves had always a tendency
depending upon their thickness and width, to produce cros
currents; and he considered that more accurate results coul
have been obtained by using fine wires to form the division
and by moving the anemometer slowly over the area of each
The instrument should be fixed to the end of a suitable stick
and held on one side and in front of the operator. He (Mr
Black) had proved, to his own satisfaction, that an obstructio
placed in an airway would certainly divert the air-current and
cause it to move obliquely; and these cross currents assuredly
would cause the anemometer to indicate an erroneous velocity.

The discussion was adjourned.

HEADING BY LONGWALL MACHINES.

By SAM MAVOR.

Introduction.

The problems associated with the driving of headings are many, but the branch of the subject to be dealt with in this paper relates only to the advancing of working-places of sufficient width to permit of the stowage of the material ripped from two or more roadways, and in seams under, say, 4 feet thick. The method advocated has no reference to stoop-and-room working, nor to other cases where the mining conditions compel close places.

The purposes for which it may be necessary to drive advance-workings into a coal-field may be roughly classified as follows:—(1) Winning out working-faces; (2) exploration to prove the field; and (3) advancing to a boundary for retreating longwall working.

The driving of a heading is not in itself an end, but is merely preliminary or preparatory to operations on a more extended scale, and therefore it is usually of importance that the work should be expeditiously carried out. A frequent consequence of the necessity for rapid advance is the sacrifice of economy in the conduct of this operation. An endeavour will be made to show that the advent of powerful machines to the coal-face has so altered the possibilities that economy may be allied to rapidity of advance.

Types of Heading Machines.

The high cost and slow advance of headings driven by hand-labour, and the necessity for selecting the best miners for this work, have stimulated a demand for mechanical aid, and response has been made by machines of three types, namely:—(1) Rotary heading machines; (2) channelling machines; and (3) chain-breast machines. To this list the longwall bar-type of coal-cutter may now be added.

Rotary Heading Machines.—Rotary heading machi considerable vogue in the Midland counties for drivin thick coal-seams, but the type does not appear to be to the conditions prevailing in this district, and does n detailed reference here.

Channelling Machines.—Channelling machines described as mechanically operated and hand-controlle tools, and they may be used with advantage under usually associated with hand-labour. Their sphere is in close places and steep seams, where portability an ence of handling are primary considerations, and material to be holed is exceptionally hard. Unde conditions the of undercuttin tively slow; an exceeding 10 o width, machine weight and pow assert their over the channe When channe chines are use sometimes are, a series of se cuts along a f cannot be descri row, the effec of the machin position, is redu

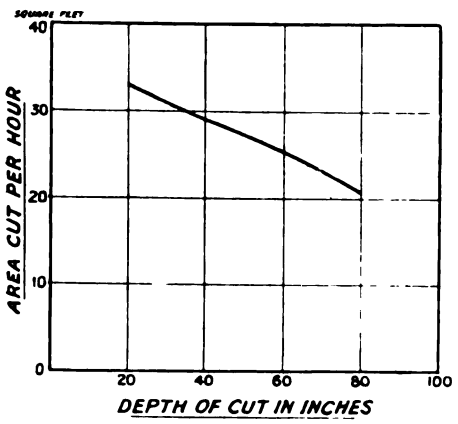

FIG. 1.—CURVE SHOWING THE RELATION OF THE DEPTH OF THE UNDERCUT TO THE WORK DONE BY A CHANNELLING MACHINE.

necessity of overlapping, in order to avoid leaving pieces uncut between the semicircular sweeps of the t type of machine is less effective in deep than in relativ undercutting. The accompanying curve (fig. 1) has b from data given in the *Report of the Committee of th England Institute of Mining and Mechanical Engi Mechanical Coal-cutting.** This shows the relation of of cut to the number of square feet cut per hour by th The writer is not aware of any satisfactory soluti

* Part II.—Heading Machines, page 43.

problem of operating the percussive type of machine directly by electricity, and the necessity of providing compressed air is frequently a bar to the adoption of this type.

Chain-breast Machines.—Chain-breast machines are most usefully employed for driving close places in thick seams, or in stoop-and-room working, where the roof is good, the holing not very hard, the seams not steep, and where the rooms are wide; the best performance, relatively to other machines and subject to the above limitations, is probably attained in places which are 24 to 36 feet wide. The effective width of the cut made by the chain-breast machine, in each position, is reduced by about 6 inches by the necessity of overlapping in order to avoid the leaving of triangular pieces at the back of the cut.

Longwall Bar Coal-cutters.—The longwall bar coal-cutter, the use of which the writer advocates for heading, is too well known in this district to require description here. The standard Pick-quick machine of medium or small size, with a cutter-bar of requisite length, is suitable, without further modification, to the advance of places 90 feet wide. In connection with the application of bar machines to heading work, it is permissible to emphasize the distinction between this machine and the bar type of heading machine which has been used in America. The latter is of the breast type in which the bar, carried by a rectangular frame, is advanced into the cut in a direction at right angles to the face similarly to the chain-breast machine. The feature of the longwall bar machine, especially adapting it for heading work, is the arrangement which enables it to cut-in at one end of the face and to cut-out at the other—thus avoiding the necessity for stable-holes.

Performance of Machines.

There is wide divergence between the best performance of any machine under test or specially prepared conditions and in the hands of a skilled operator, as compared with the average performance of similar machines, subjected to varying and often adverse conditions, and to unskilled or unintelligent manipulation. This is especially true of all machines of portable type, in which the personal factor of the operator is so important,

and to this class heading machines belong. The *Report*,* already referred to, contains data relating to the performance of channelling and chain-breast machines which illustrate the point. The amount and character of the details of the various examples cited in the *Report* are not identical, but the writer has endeavoured to compile from them the averages relating to about thirty machines (Table I.). The incompleteness of the information

TABLE I.—AVERAGE RESULTS OF UNDERCUTTING IN HEADINGS BY CHANNELLING, CHAIN-BREAST AND LONGWALL BAR MACHINES.

Type of Machine.	Channelling.	Chain-breast.	Bar.
	A*	B*	C
Thickness of seam	3 ft. 10 in.	4 ft. 0 in.	3 ft. 0 in.
Width of place	12 ft.	30 ft.	90 ft.
Height of roadway	6 ft. 6 in.	6 ft. 6 in.	6 ft. 6 in.
Depth of undercut	4 ft. 6 in.	5 ft. 8 in.	6 ft.
Rate of advance per day ...	4 ft. 6 in.	5 ft. 8 in.	6 ft.
Increase in rate of advance compared with hand-work ...	84 per cent.	105 per cent.	...
Area undercut per hour	14·5 sq. ft.	32 sq. ft.	67 sq. ft.
Area undercut per shift of 8 hours	13 sq. yds.	29 sq. yds.	60 sq. yds.
Cost of machine-labour, per shift	15s.	17s.	£1 4s.
Labour-saving, as compared with hand-work	31·5 per cent.	46 per cent.	...
	D	E	F
Interest, depreciation and repairs per shift	2s.	6s.	6s.
Power-supply, per shift	2s. 2d.	2s. 5d.	3s. 9d.
Do. per square yard ...	2d.	1d.	¾d.
Total cost of undercutting, including labour, per shift ...	19s. 2d.	£1 5s. 5d.	£1 13s. 9d.
Total cost per square yard ...	1s. 8·4d.	1s. 1·2d.	0s. 6·75d.
Labour cost per square yard, by hand	1s. 11·5d.	1s. 4·4d.	...
Net saving in cost, effected by machine	3·1d.	3·2d.	...

* These columns contain the average results of the performances detailed in the *Report of the Committee of the North of England Institute of Mining and Mechanical Engineers upon Mechanical Coal-cutting*, 1905.

available in respect of some of the examples precludes exactness from this table, but it may be accepted as approximately correct. The upper columns, A and B, give the averages of the performances detailed in the *Report*. The lower columns, D and E, are deduced from the upper columns, with the addition of the items "interest, etc.," and "power-supply:" items which are frequently omitted from comparisons of machine with hand-costs. Columns C and F relate to the performance of a deep undercutting Pick-quick bar coal-cutter, of the standard longwall type, operating

* Part II.—Heading Machines, page 43.

on a face 90 feet wide. The table simply gives a comparison of the amount and cost of undercutting by the respective machines. It will be seen from Table I. that the average saving effected in the cost of undercutting by channelling and by chain-breast machines was, under the respective conditions of operating, approximately the same, the amount of saving being slightly over 3d. per square yard. The money directly saved by undercutting with these machines, instead of by hand, in a heading 9 feet wide advanced 100 yards, would therefore appear to be only about £4, and the inducement to use machines must be found in the accelerated rate of advance, rather than in reduced cost.

It may be objected that it is unfair to compare a single example of the bar machine with the averages of a number of the other two types, but a number of examples of the use of the bar machine in headings 90 feet wide is not yet available. The case given, however, refers to the driving of a very wet dip working, in which the conditions were extremely unfavourable to any type of machine, and would have been still more so to hand-working. The only other example of which the writer has data is much more favourable to the bar machine, owing to the place, which was undercut 6 feet deep by a medium-sized machine, being considerably wider. The wider the place, up to the limit of capacity of the machine, the less will be the cost of undercutting by the bar machine.

It is to be noted that the average performance of the channelling machine is equivalent to undercutting two places, also that the chain-breast machine, if advancing for heading purposes, a place of sufficient width to permit of forming two roads, would give better results than are shown in Table I. Of the chain-breast machines referred to in the above cited *Report* as being at work in this country, the one that gave the best results operated in a winning place, 45 feet wide, and the average time required to undercut this place to a depth of 5½ feet was 8 hours.

Method of Working.

The suggestion, which is the purpose of this paper, is not revolutionary in character. It accepts an established and widely practised system of advancing headings by hand-labour, and merely advocates the use of the deep cutting-bar machine under

existing mining conditions. It is especially applicable to thi seams, in which it is necessary to advance a place of considerabl width in order to provide space in the goaf for the stowage o material ripped from the roadways. Fig. 2 is intended to repre sent a heading by which a pair of roads are advanced; the syste has many variants, but the example shown, relating to a sea $2\frac{1}{2}$ feet thick, will serve for its general illustration. Under th conditions indicated by fig. 2, the whole space, 90 feet wid (except the roadways, *a*, 12 feet wide, and, *b*, 8 feet wide, an the two cundies, *c*, 5 feet wide), is required to contain the ripp material. I seams thinne than $2\frac{1}{2}$ feet, place wider th 90 feet (assu ing the roa ways to be of t stated dime sions) would required to c tain the rip material. thicker seam less width wo be sufficient provide f stowage, but is recommend where the b machine is us that the mi mum width place should 90 feet, a cund being left in the centre of the waste between the road-packwal No gain in rate of progress would accrue from forming a narrow place, but the output would be reduced and the costs increased.

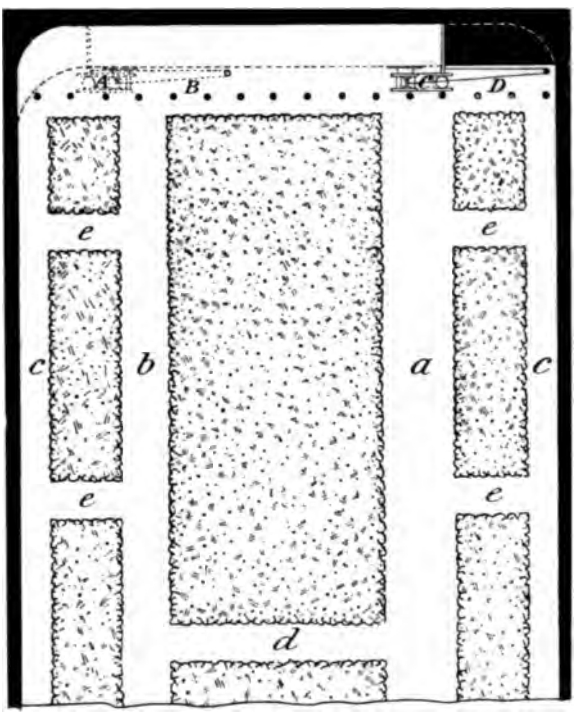

FIG. 2.—PLAN OF A HEADING, 90 FEET WIDE, WITH TWO ROADS. SCALE, 32 FEET TO 1 INCH.

As indicated by fig. 2, the bar cuts into the coal at tl position, A. When the machine reaches the second road-end, it is turned there, and cuts, with the bar leading, to the end

the face, D, where the bar is swept through a quarter-circle thus cutting-out. On the return journey, the process is repeated, the machine being turned at the second road-end, B. On a nearly level floor and under a good roof, the machine can be turned in half-an-hour. When driving to the dip, one end of the face should be kept slightly in advance of the other, so that water will flow to this end, where it can be dealt with by a pump.

When bar-machines are used in the manner described, the rate of advance of the heading is limited only by the time required to fill the coal. Experience of the method has shown that a place, 90 feet wide, can be advanced, by a machine undercutting 6 feet deep, at the rate of 36 feet per week. Regular advance at this rate requires the application of vigorous supervision to ensure the stripping of the face. The wider the heading, the more difficult it is to apply and maintain the requisite pressure; and it is suggested, where the coal is hand-filled and where quick advance is a primary consideration, that a length of 90 feet of face should not be much exceeded. There is loss instead of gain in attempting too much; failure to strip the face in one day means the sacrifice of one day's forward progress, and the deeper the cut the greater will be the loss. If, however, arrangements can be made for filling the coal with certainty, economy will be effected by increasing the width of the heading up to the limit of the capacity of the machine to cut regularly across it in one shift. The time required to place the machine in position preparatory to beginning to cut, and the time required to turn the machine, are constant for any length of face. With a face longer than 90 feet, therefore, a greater proportion of the shift will be spent in productive work.

The depth of the undercut in a seam over 2 feet thick may, so far as the machine is concerned, be anything up to 6 feet. The medium-sized Pick-quick coal-cutter, which on a longwall face normally cuts between 3 and 4 feet deep in moderate fire-clay or coal-holing at the rate of 18 inches per minute, will undercut 6 feet deep at the rate of about 12 inches per minute. If rapidity of advance were not a primary aim, an undercut 4½ feet deep would probably be considered sufficient and the small size Pick-quick, which normally undercuts 3 to 3¼ feet deep, and which with skids weighs only 28 cwts., is well suited for this duty. In hard-holing the rate of progress along the face might

be half that attained on a longwall with a shallower cut, but the distance to be traversed is only one-third or one-fourth of a longwall face, and there is ample time to cut through and to turn the machine in a shift.

If any exceptional conditions render it impossible in the time available to fill the coal when undercut to the depth indicated, or if other considerations dictate a shallower undercut, this can readily be adjusted by the use of a shorter cutter-bar.

A medium-sized machine was recently set to work with a 6 feet bar, on a face 72 feet long between a rib-side and a roadway at an angle with it. The face was advanced 6 feet each cutting shift, until it reached 240 feet in length. Owing to a scarcity of men it was found impossible to strip the face each day, and a shorter bar was inserted in order to give an undercut 4½ feet deep, and to reduce the yield of coal within the capacity of the fillers. The full advantage of deep undercutting was not in this instance realized, but its value and possibilities were amply demonstrated.

The time required to place the machine in position, to cut across a face, 90 feet wide, and to turn the machine, is, under moderately favourable conditions, about 4 hours. It should, therefore, be possible, if it were important to do so, to undercut 4½ feet deep in a seam about 2½ feet thick and to strip it in 12 hours. Filling could commence soon after the machine started to cut, and the machine-men, on the completion of the cut, could assist in filling the coal. This arrangement if the work were contracted appears practicable. The rate of advance in such a case would be 9 feet per day.

In ordinary longwall working, the rate of advance (unless the holing is exceptionally hard) depends less upon the undercutting than upon the rapid stripping of the face. The same truth applies with greater force to a heading worked by a longwall machine. With well-organized hand-filling, machine cutting, as advocated for headings, had in practice proved to be much more rapid and economical than hand-holing. But the possibilities of economy in driving headings are not exhausted by machine-holing. The mechanical conveyor, as an adjunct to the coal-cutter in a heading 135 feet or 150 feet wide, would greatly augment the effectiveness of the method proposed. Indeed, it will only be by the co-operation of the conveyor that the full advantage of the method will be realized.

ı view of the larger output which would be yielded from ıce workings by the method proposed, reference may appro-ely be made to auxiliary haulages—appliances which might profit be much more generally adopted. This district com- unfavourably with some others in regard to the use of ically-driven portable or semi-portable haulages for iary purposes. It is to be remembered that wherever

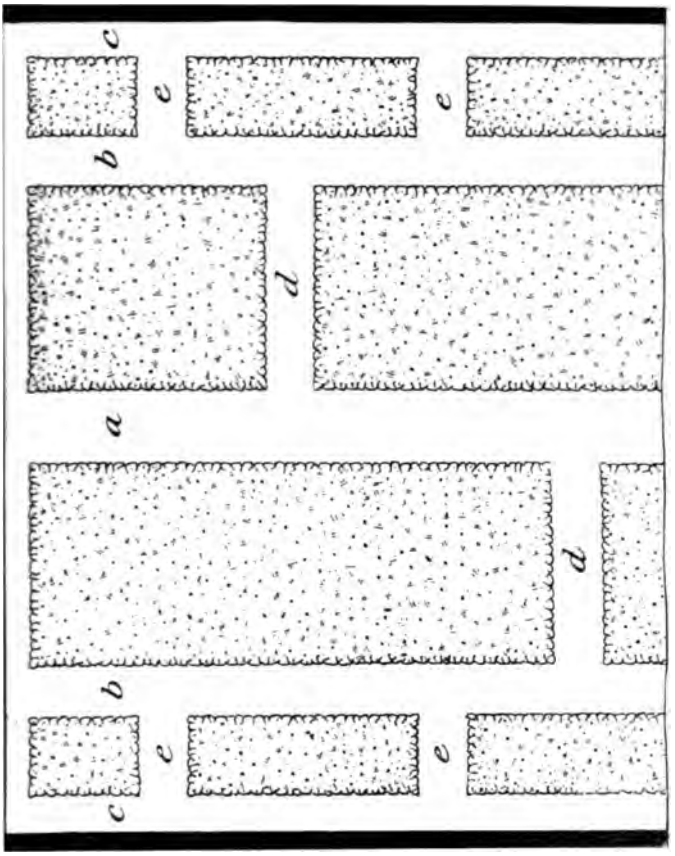

FIG. 3.—PLAN OF A HEADING, 135 FEET WIDE, WITH THREE ROADS. SCALE, 32 FEET TO 1 INCH.

ectric coal-cutter works at night, a cable is in the daytime able to supply electric power, and this could often be used advantage in connection with auxiliary haulage.

. would appear that every advantage attending the use of .ines on longwall faces would apply in greater measure to se of the bar machine for advancing headings, and these in

addition to the special desideratum of rapidity of progress. The driving of headings by hand costs a considerably higher rate per ton, especially in dip workings, than hand-labour in the same seam on longwall faces. Yet in the example already referred to, the costs of driving a very wet dip working, 90 feet wide, by a bar machine, closely corresponded to the costs of longwall working by machines in the same seam. Most colliery managers in the district have experience of machines on longwall faces, they know why they are using them in rapidly increasing numbers; they also know the amount of direct saving in costs, and the incidental advantages and economies effected by these machines. Members are, therefore, themselves in the best position to estimate the saving to be gained by the application of machines in the manner suggested, to the conditions with which they individually have to deal, and to make their own valuation of the benefits to be realized.

For winning-out, the face might suitably be 135 feet wide; a haulage-road, *a*, being formed in the centre (12 feet wide); side roads, *b* and *b* (8 feet wide), on each side; two cundies, *c* (6 feet wide); and cross-gates, *d* and *e*, as indicated in a general way by fig. 3. As the winning heading advances, longwall-machine faces are thus prepared on either side, and as these longwall faces when worked recede from the haulage-road, slant-roads may be formed to cut off the cross-gates.

Advantages.

The special advantages resulting from the use of longwall bar coal-cutters in heading work may be summarized as follows:— (1) The avoidance of hand-holing at the face when holing is most difficult, that is, before the roof-pressure comes on the coal-face. (2) A substantial output in good condition is obtained from the heading at low cost. (3) Rapidity of advance is secured without any sacrifice of economy. (4) Ample stowage-room for the ripped material encourages the formation of haulage-roads of liberal width. (5) For exploration-purposes, the wide heading reveals more than a narrow one. (6) Heading by a bar machine requires the same class of labour as an ordinary longwall face, whereas for heading by hand skilled men must be picked, and these are withdrawn from more productive work with a consequent reduction of output. Assuming, as possible, a rate of

progress by hand-working equal to that made by the machine, double the number of men, skilled men, would be required. (7) The machine used for winning-out only requires a change of cutter-bar to adapt it for longwall working.

The added advantages gained by machines may extend the system represented by figs. 2 and 3, or some modification of it, into seams the thickness of which has hitherto excluded it. Where thick seams are worked on the panel system, the deep undercutting-bar, used as described, would yield excellent results.

Limitations.

Steepness of the seam, within the usual limitations in this country, is not a bar to success. The method advocated can be applied in seams inclined 1 in 3½, and faces can be advanced straight to the dip, straight to the rise, or at a right angle to the line of dip.

The nature of the roof may prohibit an undercut so deep as 6 feet. In such a case, the bar can be shortened so as to meet the conditions. It should be remembered that, with an undercut of 4 feet or more, the machine is under a new roof for each cut.

The system of heading now under review is, of course, not universally applicable, and the limitations which apply to the system when operated by hand would, for the most part, be valid as regards machine-working, but there are few cases in which it could be adopted and worked by hand where it could not be worked to greater advantage by the bar machine.

The limit of thickness of seam to which the system could be usefully applied must depend upon local conditions. It is probably about 4½ feet, but other limitations may emerge in the discussion.

It is probable that increasing experience in the application of longwall machines and fuller acquaintance with their capabilities will tend to a progressive diminution of narrow work. In plans of new workings its complete abolition has already been forecast by mining engineers of wide experience in the handling of machines.

THE NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD AT THE NORTH STAFFORD HOTEL, STOKE-UPON-TRENT,
FEBRUARY 4TH, 1907.

MR. JOHN NEWTON, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen, having been previously nominated, were elected:—

MEMBER—
Mr. H. JOHNSTONE, H.M. Inspector of Mines, Stafford.

ASSOCIATE—
Mr. JOHN BENTLEY, Crackley Colliery, Chesterton.

DEATH OF MR. W. H. DAVIES.

The PRESIDENT (Mr. John Newton) said that, since their last meeting, they had sustained a loss in the death of one of their most esteemed and respected members. He referred to the late Mr. W. H. Davies, general manager of the Shelton Iron, Steel and Coal Company, Limited. The Council had decided to send a letter of condolence, but they felt that an expression of sympathy coming from the whole of the members of the Institute ought to be forwarded. Mr. Davies had been a member of the Institute since he came to the district, and he had gained the respect of everybody who knew him. Steel-making had been a difficult process in North Staffordshire, as everything had militated against its manufacture, particularly their inland position and the railway-difficulties with which they had to contend. Mr.

Davies had taken up the work of lessening those difficulties, and if he had lived something would have been done to relieve the pressure that crippled the manufacture of steel by facilitating its export out of the district. He moved that a letter of condolence be sent from the Institute to the widow and family, expressing its profound regret at the irreparable loss that they had sustained, and he would ask the members to rise in their places, so as to show their feeling in this matter.

The resolution was carried by the members standing up in silence.

PRIZES.

The PRESIDENT (Mr. John Newton) presented prizes to the writers of the following papers:—

"Notes on the Feed-water of Colliery-boilers." By Mr. A. E. Cooke.
"A Gob-fire in the Ten-feet Seam, North Staffordshire." By Mr. W. G. Peasegood

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Mr. ST. V. CHAMPION JONES read the following paper on "A Gob-fire in a Shropshire Mine":—

A GOB-FIRE IN A SHROPSHIRE MINE.

By ST. V. CHAMPION JONES.

This gob-fire occurred about the middle of 1906, at th hold colliery, belonging to the Lilleshall Company, Limite

Before dealing directly with the fire, it will be desirable a brief outline of the geological disturbances to which the at this colliery have been subjected, and a few particula regard to the practical working.

The general average dip of the measures, througho district, is 1 in 12 in a north-easterly direction, and it is evenly maintained until within about 150 feet from the sl the Freehold colliery. There is then a gradual lessening rate of dip until the strata reach the horizontal positio thence they rise very rapidly northward until a ma gradient of 45 degrees is reached. The gob-fire broke out steep workings of the Double coal-seam (fig. 1, plate i.). sudden upheaval of the measures is in all probability due wellknown landmark known as Lilleshall hill, consisting eruptive igneous rock protruding about 200 feet above t rounding surface. The outcrop of some of the coal-seam been traced to within about $\frac{3}{4}$ mile from the foot of this h it is towards this outcrop that the present coal-face is adv

The depth at the shafts to the Double coal-seam feet; but, owing to the abnormal rise of the measures, the from the surface to the point where the fire occurred wo be more than 330 feet (fig. 2, plate i.).

The following is a section of the Double coal-seam:—

		Ft.	Ins.	Ft.	Ins.
Roof:	Rock	2	0		
	COAL, with nodules ...	0	9		
	Rock	2	0		
	False rock	1	0		
				5	9
Seam:	**COAL**	5	6		
				5	6
Floor:	Dark shale	1	9		
				1	9

able height, and as it was considered impracticable to attempt
ig it out, it was decided to seal it off by means of a
:-wall. A rock-building, *a*, was therefore built across the
e, and a brick-and-mortar wall, *e*, 14 inches thick, was built
ront of it, from the coal-pillar on the left to the top of
ell's jig; and it was continued down this jig, as it was found
carbon dioxide was making its way through the jig-side
:-wall. This wall was carried down the jig in sections, 12
long, each section being built up-hill against the ventilating
ent. This method was adopted, as it was ascertained that,
a bricking downhill, the carbon dioxide found its way, along
back of the wall, to the bricklayers working at the end of it;
this notwithstanding that 15,000 cubic feet of air per minute
passing down the jig. A space of 18 inches was left at the
: of the wall, and this was filled with black sand, *c*, as the
:-wall was erected.

Actual gob-stink was first noticed at B (fig. 3, plate i.),
it 8 weeks after heating was perceived at A; and a stopping
at once erected at this point between the coal-pillar and the
A brick-wall, *e*, 18 inches thick, was also carried up the side
is cog, and black sand, *c*, was rammed behind it. As an extra
aution, the wastes, C, D and E, were built off by means of dirt-
sand stanks; and the waste, E, was further sealed by means of
ick-and-mortar wall, *e*, 18 inches thick, a slight trace of gob-
: having been noticed at this point.

While the brick-wall was being built down the side of Powell's

the jigs, to the place where it was required. The bricks, sand and mortar were conveyed up Wakeley's and Darlington's jigs against tubs of coal (the gradient in these jigs being about 45 degrees), and carried along the face.

The solid coal-pillar (figs. 1 and 3, plate i.), consisted of soft faulted coal, with numerous slips in it, and the seam was about 12 feet thick, that is, more than twice the normal thickness. The coal here was of so soft a nature that it could be ground to powder in the hand, with very little effort. This pillar had been left, as it was not considered safe to work the coal at that point owing to the exceptionally bad nature of the roof, and because there was not sufficient material for cogging purposes.

On Saturday, June 2nd, 1906, the condition generally seemed to be much improved, and the brick-wall in Powell's jig had reached a point about 30 feet from the underlying level. The thermometer, which was hung against the brick-wall about half-way down the jig, where the temperature was highest, showed that the temperature was decreasing. It had never been higher than 69° Fahr.; but, at this time, it was only 67°; and the place seemed to be cooling down. However, on the following Monday, June 4th, the fireman reported that a thin stream of smoke, about as thick as his arm, was making its way from the rise-side H, of a dirt-stank, *b*, in the level at the bottom of Powell's jig. Men were at once dispatched to the place with the object of trying to build a wall along the disused part of the level, to the coal-pillar, as had been originally intended, so as to seal the waste on all sides, and prevent the heating from extending to the gob on the lower side of the level.

All went well until Wednesday evening, June 6th, the level having been cleaned up about 15 feet from the bottom of the jig, and a brick-wall partly put in on the top side. The under-manager and the writer, on arrival at the pit, were informed that the men working in the place had come out, stating that there had been a fall in the level where they were working, bringing a live fire with it and a quantity of smoke; and that they were compelled to beat a hasty retreat. The writer at once descended the pit, and as soon as he had passed through the two doors, R, into the return-airway, he perceived that it was charged with dense smoke, and it was only possible to see a few feet in advance. He therefore decided to try and reach the fire from the

intake-airway, and accordingly he travelled up Darlington's jig and along the face to Powell's jig, down which he proceeded till he got to within a few feet of the bottom. At this point, further progress was arrested by white smoke, so thick that he could not see more than a foot in advance, and a lamp held in it was extinguished almost instanteously. The fire could be heard crackling a few feet away, and a faint red glow could just be seen through the smoke. He then returned up Powell's jig, and along the face to the top of Wakeley's jig, and partly lifted the brattice-sheet, O, in order to take more fresh air down the jig. On returning down the jig and reaching the level below, he was surprised to find that it was practically free from smoke, and, looking along it, he could see the fire blazing at the far end. He then proceeded along the level to the bottom of Powell's jig and within a few feet of the fire. When this point was reached, it was seen that an unexpected change had occurred in the ventilation, as the smoke and fumes from the fire were ascending Powell's jig in large volumes. He, therefore, beat a hasty retreat into a current of fresh air, coming along the level, just beyond the bottom of Wakeley's jig. This point was reached just in time to escape the smoke which was rolling down Wakeley's jig.

Under ordinary conditions, two splits of air united at the top of Powell's jig; the one from the west ventilated the pack-level district, and the one from the east came from the Muxton-Bridge pits, about ½ a mile distant, which ceased to wind coal about a year ago. The united air-current travelled down Powell's jig and an abandoned jig, on to the main or new-opening level below. When the brattice-sheet, O, was lifted in Wakeley's jig, part of the ventilating current from the Muxton-Bridge district naturally short-circuited down the jig: this decreased the air-current in Powell's jig, and consequently the heated air from the fire was able to form a motive column in this jig and so reverse the air-current. This was an instance (which was certainly unique in the writer's experience) of the ventilation going the longest way round, instead of taking the shortest, and, under ordinary circumstances, the easiest, direction; and had the mine been anything but highly inclined, the writer is of opinion that this change would not have taken place.

Matters were then looking very serious, and, after a somewhat

lengthy discussion, the writer came to the conclusion that, a least, the whole of the new-opening district would have to b abandoned, by building stoppings and sealing it off. But it coul be recognized that even this would be no easy matter to accom plish effectively, as the east side of the face was stripping som old workings, which had been abandoned about 4 years ago; an the roadways and workings were still in a fairly open state, s that the only way of building satisfactory stoppings on this sid was to go right back to the Muxton-Bridge pits and build the in the shaft-pillar. Brick-and-mortar stoppings were therefo built at J, K, L and M (fig. 1, plate i.). On the west side, was decided to build a main stopping, N, in the new-openi level, and another, P, at the coal-face, up Darlington's j Stoppings, U and V, were also erected in the old headings on t east side of the Freehold pits. The main stopping, N, in t new-opening level consisted of two brick-and-mortar walls, ea 3 feet thick, 6 feet apart, built well into the sides, as the grou was much broken. Between these walls, two brick-walls, 9 inch thick, were built at right angles and about 2 feet apart, so th the stopping could be completed, with the exception of a sm hole about 2 feet square, which could be quickly closed as soon the other stoppings were completed. Black sand, from t foundry, was used for filling between the walls and was ramm solid with wooden rammers. The building of this stopping w carried out under considerable difficulties, on account of its bei in the return-airway from the fire; and, although fresh air w taken in to the men by means of a range of air-pipes, it was fou necessary to divide the men into three divisions, each division o being allowed to remain at the stopping for 3 minutes bef being relieved by the next: 5 minutes was allowed at first, b this time was reduced to 3 minutes as some of the men co plained of feeling bad, and showed signs of carbon-monox poisoning.

The stopping, P, at the coal-face up Darlington's jig was bu in the following manner: a dirt-and-sand building, *d*, 4 f thick, was built across from the coal-face to the cog; and 3 f distant from this, a brick-wall, *e*, 9 inches thick, was built, a the intervening space was filled with black sand, *c*. The stoppi was built with a brick-wall, only 9 inches thick, owing to t difficulty of getting a sufficient supply of bricks and mortar

the jigs. While this stopping was being built, a temporary stopping was erected at the bend in the heading, FG, and in the airway, BF, between the brick-wall and the west side of the coal-pillar. These stoppings were made with slack-coal, the only material at hand.

Previous to these stoppings being erected, smoke with carbon dioxide was backing along the coal-face towards the place where the permanent stopping was being built: consequently the situation was much improved by the erection of these slack-coal stoppings.

The main stopping, K, near the Muxton-Bridge pits, and the main stopping, N, in the new-opening level, were the last to be closed. It was arranged that they should be closed simultaneously; but, as a matter of fact, the Muxton-Bridge stopping was closed a few minutes before the other.

The fire was, in the writer's opinion, due to the oxidation of coal, without the assistance of pyrites. Pyrites is met with occasionally embedded in the coal in the form of lumps, but it is not found in sufficient quantities to justify the opinion that the origin of the fire was, either partly or wholly, due to its presence. The coal, at the point where the fire started, had the appearance of being highly carbonized, and looked as if it had, at some time or another, been subjected to great friction. It is not thought that such friction or pressure contributed to the fire in the present instance, except from the fact of the coal being crushed into small pieces and consequently rendering it more liable to oxidation.

Similar belts of soft, sooty coal had occurred in other parts of this seam, and fires had been frequent; but there had never been any signs of heating when the coal had been strong and in its normal condition.

At the Granville colliery, about 1½ miles distant, where the Double seam had been extensively worked, a fire had never been known to occur.

The conditions prevailing at the present time are as follows:—The stopping, N, in the new-opening level has been strengthened by sand-and-brick walls, and has now a total thickness of 45 feet. A pipe, 2 inches in diameter, has been fitted through the stopping; and, on the valve being opened, carbon

dioxide issues from it under slight pressure. A light is extinguished in a few seconds when held at the end of the pipe. The temperature on the wall of this stopping is 81° Fahr., and this has been constant for some months.

The stopping, P, at the coal-face of Darlington's jig has also been strengthened by filling the face from the stopping to the jig-side, with riddled slack-coal and sand, *g*. The temperature is 62° Fahr.

A roadway, S to T, has been driven in the gob of the Top coal-seam, about 18 feet above the Double seam (fig. 1, plate i.). This roadway provides an auxiliary airway, so that the roadways to the west of the coal-pillar could be closed, should the fire show signs of eating its way into them. At the present time, there are no indications of the fire breaking through, and the writer hopes that it has been satisfactorily enclosed.

Mr. F. H. Wynne said that the coal in the pillar was faulted, of a peculiar character, and a handful could be crushed to powder by simple pressure. He had taken samples of the soft and of the hard coal, and had hoped to have made experiments as to their relative speeds of oxidation; but, owing to the removal of the county laboratory and other matters, the experiments had not been completed.

Mr. St. V. C. Jones said that fires in the Freehold pit had always occurred where the soft and sooty coal was found. He could obtain samples of coal which would be similar to those obtained at the point of the fire.

Mr. B. Woodworth asked whether the sooty coal was caused by the bending of the strata, and whether fires had occurred at the Granville pit.

Mr. St. V. C. Jones thought that the bending of the strata had a connexion with the formation of the soft, sooty coal. He thought that the upheaval of the Coal-measures was probably due to the igneous intrusion, which now formed Lilleshall hill. The Coal-measures were crushed and broken, and this band of soft sooty coal was then produced. Fires had only occurred in the soft sooty bands of the Freehold pits, and he thought that, owing to their absence, no fires had occurred at the Granville pits.

rs had been left. He contended that, at any expense, a
ow pillar should be removed, for what was the cost of work-
such a pillar when compared with the loss of a district?
efore, the warning of the paper should be not to leave narrow
rs of friable coal.

Mr. G. E. Lawton asked whether the roof-coal was recovered
. the goaf, and, if not, possibly this coal might be the means
nitiating a gob-fire. He thought that Dr. J. S. Haldane
ed conclusively that pyrites, when finely disseminated in a
, actively participated in propagating gob-fires, as it
ed disintegration of the coal and exposed larger surfaces
of to oxidation. But he did not think that, when found in
lump-form, pyrites assisted in producing gob-fires.

Mr. A. M. Henshaw said that this interesting paper intro-
ed once more a question of vital importance to all engineers
rested in coal-mining in North Staffordshire and the neigh-
ring county. The seam, in its natural condition, was not sub-
to spontaneous combustion, but a gob-fire had occurred under
umstances that were abnormal. The cause was found in the
litions of the seam at the seat of the fire; and at that point the
was very faulted, very friable, very thick, and so soft that, by
pressure of the hand, a lump could be squeezed into dust.
ilst that condition of the seam obtained in that area, probably
h the very best intentions but with the most unfortunate
lts, a course was adopted, which, from his experience of work-
seams much prone to spontaneous combustion, he would at
describe as extremely risky. He had had a number of cases

would be very difficult to remove entirely the whole of the coal. He presumed that the district was sufficiently well-known, so as to determine the direction and extent of that faulty area. In that case, he would have suggested that a larger area, including all the soft coal and a certain margin of natural strata alongside of it, without cutting places through, should have been left absolutely solid. The fire broke out, at A, in a small area of goaf and alongside a pillar of faulted coal (fig. 3, plate i.). Several places appeared to have been driven through the faulted coal, from one side to another, and at the same time the natural tendency of the ventilating current was from west to east, so that it was very likely that some leakage of air would pass from west to east into the middle of the gob, A. It was quite conceivable, owing to the coal being so soft, inferior and thick, that the gob, A, would contain a considerable quantity of waste-coal and the forcing of a small quantity of air into that mass would be sufficient to encourage oxidation. It probably would not be sufficient to bring about the necessary cooling, but it would be sufficient to supply new oxygen and to increase the temperature until it attained the ignition-stage. It was always easy to judge and draw conclusions after the event, and he always sympathized with engineers who had to deal with gob-fires. He invariably found that they were more to be pitied than blamed, but he wanted for the purpose of information to draw useful lessons from the cases that came before the notice of the members. As to the question of pyrites, he did not see that pyrites need have had anything to do with the fire: it was due to the soft and broken condition of the coal; and, with multiplied surfaces exposed to oxidation, a rising temperature was naturally propagated.

With regard to the method of dealing with the gob-fire, it showed a great deal of pluck and ingenuity on the part of Mr. Jones and his staff, and he was to be congratulated upon the efforts that he had made to confine the fire, in the early stages, within close quarters. Considerable risks appeared to have been encountered, and he asked whether they had to deal with fire-damp.

Mr. St. V. C. Jones replied that a little fire-damp had been found occasionally, and a small percentage was found when driving the heading from F to G (fig. 3, plate i.).

Mr. A. M. Henshaw said that part of the scheme suggested by Mr. Jones was the filling of the road, above A, between the pack-wall and the solid pillar above, and he supposed that it would be 8 or 9 feet wide. He had tried the plan of filling with non-inflammable material, but he had found that 8 or 9 feet of sand was not sufficient to prevent the conduction of heat to the solid coal beyond, and the heat would be sufficient to fire the pillar on the other side of it. A long time seemed to have elapsed between the outbreak on April 5th and the evidence of real fire on June 6th, and he asked whether, during that time, any real fire had been seen. Mr. Jones had stated in his paper that the coal at the point where the fire started had the appearance of being "highly carbonized, and looked as if it had . . . been subjected to great friction." He would like to have a clearer idea of the meaning of "highly carbonized," as he did not think that Mr. Jones meant the effect produced by heat, and he imagined that it would be similar to the "mushy coal" of that district. Great credit was due to Mr. Jones for his efforts, but he should have regarded the plan of fighting the fire, at close quarters, as hopeless from the first in an area of longwall, and with a current of 15,000 cubic feet of air per minute. He thought that they were bound to be driven back to erect permanent stoppings in the main roads. He could hardly judge the conditions, but he thought it was possible that the fire might, some day, be observed at the entrances of some of these roads, probably on the margin of the pillar of soft coal that had been left. He should advise Mr. Jones to strengthen the stoppings at Darlington's jig, on the face, and wherever possible. From what Mr. Jones had said of the pressure of the carbon dioxide in the pipe carried through the stopping in the new-opening level, he would imagine that air was finding an entrance; and if Mr. Jones could build side-walls alongside Darlington's jig, and reduce the pressure of the air into the heated goaf, he would be taking a further wise precaution.

Mr. A. Hassam, in moving a vote of thanks to Mr. Jones for his paper, asked whether there was any water or damp about the seam.

Mr. St. V. C. Jones said that there was no water at that point, and practically no moisture in the seam. With reference to

the leaving of the pillar, on the face of it, it looked wrong, and, from a mining point of view, it was wrong, but it was left on account of safety. The roof was wretched, and it was found that sufficient cogging material could not be procured to cog the place (the seam being about 12 feet thick at that point). They were afraid of accidents, and for that reason the pillar was left. This soft coal had been found in other portions of the Double seam, and it had with difficulty been removed. The seam being thick, a certain amount of slack fell into the gob, and fires had occurred frequently, where pillars had not been left. With regard to strengthening the stoppings and preventing the fire from coming through them, it had been decided, in case of the fire showing signs of coming through, to fill in the roadways to the west of the coal-pillar. The seam was practically free from gas, which had only been found in very small quantities. Its absence was due to the fact that the overlying seam of coal had been worked, and had practically drained it away.

The PRESIDENT seconded the vote of thanks to Mr. Jones for his paper, and it was unanimously approved.

MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE QUEEN'S HOTEL, BARNSLEY, FEBRUARY 20TH, 1907.

MR. J. R. R. WILSON, PRESIDENT, IN THE CHAIR.

The following gentlemen, having been duly nominated, were elected:—

MEMBERS—

Mr. WILLIAM BADGER, Mechanical Engineer, Jagersfontein Diamond Mining Company, Orange River Colony, South Africa.

Mr. JOHN HENRY GREAVES, Mining Engineer, 69, Westgate, Wakefield.

Mr. THOMAS WIGHTON HOOD, Engineer, 120, East Ferry Road, Millwall, London, E.

Mr. JOSEPH JAGGAR, Colliery Manager, Grange Moor Collieries, Flockton, Wakefield.

Mr. T. W. KEILLAR, Mining Engineer, Wortley, Leeds.

STUDENT—

Mr. NORMAN SAMUEL ROBERTS, Mining Student, Aldwarke Main Colliery, Rotherham.

Mr. R. SUTCLIFFE read the following paper on "The Importance of Scientific Mining in the Barnsley District":—

THE IMPORTANCE OF SCIENTIFIC MINING IN THE BARNSLEY DISTRICT.

By R. SUTCLIFFE.

Miners living but very few miles from this district, knowing something of its geological features must often ϵ those who are surrounded with so large a number of valu coal-seams, which would be highly prized in other distr especially by those who may have happened to be conne with the working of seams in which, if a man has a long p blade, he has some difficulty in turning the second point to coal when the first has become blunted. To men emplc in the getting of such seams, what is considered in the Barn district to be a thin seam, would to them appear to be a modera thick one. For clearness in this paper, the writer will assum seams under 3 feet in thickness to be " thin seams " and all se over 3 feet to be " thick ones." In thinking over the subjec mining in the neighbourhood of Barnsley, one cannot always whether the thick seam bearing the name of the town has bee that great benefit to the locality which, under other circumstan it might have been. However this may be, the fact that it is b exhausted in the neighbourhood makes it necessary for min who live in the town, to travel farther afield in order to r their daily work. As the nearest collieries, now at work, bec worked out, if the thinner seams continue to be neglected, daily journey of the miner must increase unless he moves the country; and, as human endurance is limited, it foll that the miner's power or capacity for useful or productive w will be proportionately reduced. A good service of trains exist to convey the workmen to and from their work; but w ing, even for a short time, for a train to move so starves the b especially after a day's work in a warm mine, that it is quest able whether this train-accommodation is altogether to be desi Until recently, however, these disadvantages were probe unavoidable, owing to a great extent to the inability of

ing the thin seams under and around Barnsley in the early
re is not very promising, unless improved methods of work-
are adopted. In addition to this, the difficulties of the
ery-owner in utilizing thin seams cannot be ignored;
use many departures must be made from the methods adopted
etting thick seams:—(1) The royalty-rent payable to the
lord should be much more than proportionately lower than
for the thick seam—a fact not always readily recognized by
andlord or his agents. (2) If the colliery-owner were not
very well out of his thick coal, he could hardly expect to
ove his position by embarking in the work of a thin one;
, if he was doing well out of his thick one, he would naturally
well alone," especially as he would have to meet the royalty
ion just referred to, with, perhaps, the expiration of his
also in view. (3) He would have to procure plant, corves,
uitable for thin seams, and work these while his plant,
le for the thick seam, might be lying idle.

hen it is remembered that the total thickness of coal
lying Barnsley, in the several beds which are known to be
workable thickness, exceeds 40 feet, it seems difficult to
stand why the three partners in the business could not come
mutually beneficial understanding and unlock this vast
nt of wealth, instead of letting the grand and fascinating
ry of coal-mining glide, slowly it may be, away from
wn. From the landlord's point of view, one would have
ht that the proverbial half-loaf would be better than no
especially as the working of thin seams seldom, if ever,

lengthy discussion, the writer came to the conclusion that, at least, the whole of the new-opening district would have to be abandoned, by building stoppings and sealing it off. But it could be recognized that even this would be no easy matter to accomplish effectively, as the east side of the face was stripping some old workings, which had been abandoned about 4 years ago; and the roadways and workings were still in a fairly open state, so that the only way of building satisfactory stoppings on this side was to go right back to the Muxton-Bridge pits and build them in the shaft-pillar. Brick-and-mortar stoppings were therefore built at J, K, L and M (fig. 1, plate i.). On the west side, it was decided to build a main stopping, N, in the new-opening level, and another, P, at the coal-face, up Darlington's jig. Stoppings, U and V, were also erected in the old headings on the east side of the Freehold pits. The main stopping, N, in the new-opening level consisted of two brick-and-mortar walls, each 3 feet thick, 6 feet apart, built well into the sides, as the ground was much broken. Between these walls, two brick-walls, 9 inches thick, were built at right angles and about 2 feet apart, so that the stopping could be completed, with the exception of a small hole about 2 feet square, which could be quickly closed as soon as the other stoppings were completed. Black sand, from the foundry, was used for filling between the walls and was rammed solid with wooden rammers. The building of this stopping was carried out under considerable difficulties, on account of its being in the return-airway from the fire; and, although fresh air was taken in to the men by means of a range of air-pipes, it was found necessary to divide the men into three divisions, each division only being allowed to remain at the stopping for 3 minutes before being relieved by the next: 5 minutes was allowed at first, but this time was reduced to 3 minutes as some of the men complained of feeling bad, and showed signs of carbon-monoxide poisoning.

The stopping, P, at the coal-face up Darlington's jig was built in the following manner: a dirt-and-sand building, *d*, 4 feet thick, was built across from the coal-face to the cog; and 3 feet distant from this, a brick-wall, *e*, 9 inches thick, was built, and the intervening space was filled with black sand, *c*. The stopping was built with a brick-wall, only 9 inches thick, owing to the difficulty of getting a sufficient supply of bricks and mortar up

the jigs. While this stopping was being built, a temporary stopping was erected at the bend in the heading, FG, and in the airway, BF, between the brick-wall and the west side of the coal-pillar. These stoppings were made with slack-coal, the only material at hand.

Previous to these stoppings being erected, smoke with carbon dioxide was backing along the coal-face towards the place where the permanent stopping was being built: consequently the situation was much improved by the erection of these slack-coal stoppings.

The main stopping, K, near the Muxton-Bridge pits, and the main stopping, N, in the new-opening level, were the last to be closed. It was arranged that they should be closed simultaneously; but, as a matter of fact, the Muxton-Bridge stopping was closed a few minutes before the other.

The fire was, in the writer's opinion, due to the oxidation of coal, without the assistance of pyrites. Pyrites is met with occasionally embedded in the coal in the form of lumps, but it is not found in sufficient quantities to justify the opinion that the origin of the fire was, either partly or wholly, due to its presence. The coal, at the point where the fire started, had the appearance of being highly carbonized, and looked as if it had, at some time or another, been subjected to great friction. It is not thought that such friction or pressure contributed to the fire in the present instance, except from the fact of the coal being crushed into small pieces and consequently rendering it more liable to oxidation.

Similar belts of soft, sooty coal had occurred in other parts of this seam, and fires had been frequent; but there had never been any signs of heating when the coal had been strong and in its normal condition.

At the Granville colliery, about 1½ miles distant, where the Double seam had been extensively worked, a fire had never been known to occur.

The conditions prevailing at the present time are as follows: The stopping, N, in the new-opening level has been strengthened by sand-and-brick walls, and has now a total thickness of 45 feet. A pipe, 2 inches in diameter, has been fitted through the stopping; and, on the valve being opened, carbon

dioxide issues from it under slight pressure. A light is extir guished in a few seconds when held at the end of the pipe. Th temperature on the wall of this stopping is 81° Fahr., and th has been constant for some months.

The stopping, P, at the coal-face of Darlington's jig has als been strengthened by filling the face from the stopping to th jig-side, with riddled slack-coal and sand, *g*. The temperature : 62° Fahr.

A roadway, S to T, has been driven in the gob of the To coal-seam, about 18 feet above the Double seam (fig. 1, plate i.) This roadway provides an auxiliary airway, so that the roadway to the west of the coal-pillar could be closed, should the fir show signs of eating its way into them. At the present tim there are no indications of the fire breaking through, and th writer hopes that it has been satisfactorily enclosed.

Mr. F. H. Wynne said that the coal in the pillar was faulte of a peculiar character, and a handful could be crushed to powde by simple pressure. He had taken samples of the soft and c the hard coal, and had hoped to have made experiments as t their relative speeds of oxidation; but, owing to the removal o the county laboratory and other matters, the experiments had no been completed.

Mr. St. V. C. Jones said that fires in the Freehold pit had always occurred where the soft and sooty coal was found He could obtain samples of coal which would be similar to thos obtained at the point of the fire.

Mr. B. Woodworth asked whether the sooty coal was cause by the bending of the strata, and whether fires had occurred a the Granville pit.

Mr. St. V. C. Jones thought that the bending of the strat had a connexion with the formation of the soft, sooty coal. H thought that the upheaval of the Coal-measures was probably du to the igneous intrusion, which now formed Lilleshall hill. Th Coal-measures were crushed and broken, and this band of sof sooty coal was then produced. Fires had only occurred in th soft sooty bands of the Freehold pits, and he thought that, owin to their absence, no fires had occurred at the Granville pits.

Mr. F. E. Buckley said that he had arrived at the practical conclusion that the fire had been caused by the narrow pillar of coal being left in the centre of a large gotten area; and, however difficult it might be to work that pillar of coal, in his opinion, it certainly should have been removed. Mr. Jones strengthened that opinion by stating that fires had always occurred where coal-pillars had been left. He contended that, at any expense, a narrow pillar should be removed, for what was the cost of working such a pillar when compared with the loss of a district? Therefore, the warning of the paper should be not to leave narrow pillars of friable coal.

Mr. G. E. Lawton asked whether the roof-coal was recovered from the goaf, and, if not, possibly this coal might be the means of initiating a gob-fire. He thought that Dr. J. S. Haldane proved conclusively that pyrites, when finely disseminated in a seam, actively participated in propagating gob-fires, as it caused disintegration of the coal and exposed larger surfaces thereof to oxidation. But he did not think that, when found in the lump-form, pyrites assisted in producing gob-fires.

Mr. A. M. Henshaw said that this interesting paper introduced once more a question of vital importance to all engineers interested in coal-mining in North Staffordshire and the neighbouring county. The seam, in its natural condition, was not subject to spontaneous combustion, but a gob-fire had occurred under circumstances that were abnormal. The cause was found in the conditions of the seam at the seat of the fire; and at that point the coal was very faulted, very friable, very thick, and so soft that, by the pressure of the hand, a lump could be squeezed into dust. Whilst that condition of the seam obtained in that area, probably with the very best intentions but with the most unfortunate results, a course was adopted, which, from his experience of working seams much prone to spontaneous combustion, he would at once describe as extremely risky. He had had a number of cases of gob-fires in small patches of faulted, soft and thick coal; and he had been taught by experience that wherever coal of that description was found, it should be left solid in large areas or entirely worked out. He could quite see the difficulty in this case of working out the whole of that area of soft and thick coal. The seam being 12 feet thick and part of a longwall district, it

would be very difficult to remove entirely the whole of the coa He presumed that the district was sufficiently well-known, so to determine the direction and extent of that faulty area. In th case, he would have suggested that a larger area, including all t soft coal and a certain margin of natural strata alongside of without cutting places through, should have been left absolute solid. The fire broke out, at A, in a small area of goaf and alon side a pillar of faulted coal (fig. 3, plate i.). Several plac appeared to have been driven through the faulted coal, from o side to another, and at the same time the natural tendency the ventilating current was from west to east, so that it was ve likely that some leakage of air would pass from west to east in the middle of the gob, A. It was quite conceivable, owing to t coal being so soft, inferior and thick, that the gob, A, wou contain a considerable quantity of waste-coal and the forci of a small quantity of air into that mass would be sufficient encourage oxidation. It probably would not be sufficient to bri about the necessary cooling, but it would be sufficient to supp new oxygen and to increase the temperature until it attained t ignition-stage. It was always easy to judge and draw conclusio after the event, and he always sympathized with enginee who had to deal with gob-fires. He invariably found that th were more to be pitied than blamed, but he wanted for the pu pose of information to draw useful lessons from the cases th came before the notice of the members. As to the question pyrites, he did not see that pyrites need have had anything to with the fire: it was due to the soft and broken condition of t coal; and, with multiplied surfaces exposed to oxidation, a risi temperature was naturally propagated.

With regard to the method of dealing with the gob-fire, showed a great deal of pluck and ingenuity on the part of M Jones and his staff, and he was to be congratulated upon t efforts that he had made to confine the fire, in the early stag within close quarters. Considerable risks appeared to have be encountered, and he asked whether they had to deal with fi damp.

Mr. St. V. C. Jones replied that a little fire-damp had be found occasionally, and a small percentage was found wh driving the heading from F to G (fig. 3, plate i.).

Mr. A. M. Henshaw said that part of the scheme suggested by Mr. Jones was the filling of the road, above A, between the pack-wall and the solid pillar above, and he supposed that it would be 8 or 9 feet wide. He had tried the plan of filling with non-inflammable material, but he had found that 8 or 9 feet of sand was not sufficient to prevent the conduction of heat to the solid coal beyond, and the heat would be sufficient to fire the pillar on the other side of it. A long time seemed to have elapsed between the outbreak on April 5th and the evidence of real fire on June 6th, and he asked whether, during that time, any real fire had been seen. Mr. Jones had stated in his paper that the coal at the point where the fire started had the appearance of being "highly carbonized, and looked as if it had . . . been subjected to great friction." He would like to have a clearer idea of the meaning of "highly carbonized," as he did not think that Mr. Jones meant the effect produced by heat, and he imagined that it would be similar to the "mushy coal" of that district. Great credit was due to Mr. Jones for his efforts, but he should have regarded the plan of fighting the fire, at close quarters, as hopeless from the first in an area of longwall, and with a current of 15,000 cubic feet of air per minute. He thought that they were bound to be driven back to erect permanent stoppings in the main roads. He could hardly judge the conditions, but he thought it was possible that the fire might, some day, be observed at the entrances of some of these roads, probably on the margin of the pillar of soft coal that had been left. He should advise Mr. Jones to strengthen the stoppings at Darlington's jig, on the face, and wherever possible. From what Mr. Jones had said of the pressure of the carbon dioxide in the pipe carried through the stopping in the new-opening level, he would imagine that air was finding an entrance; and if Mr. Jones could build side-walls alongside Darlington's jig, and reduce the pressure of the air into the heated goaf, he would be taking a further wise precaution.

Mr. A. Hassam, in moving a vote of thanks to Mr. Jones for his paper, asked whether there was any water or damp about the seam.

Mr. St. V. C. Jones said that there was no water at that point, and practically no moisture in the seam. With reference to

the leaving of the pillar, on the face of it, it looked wrong. from a mining point of view, it was wrong, but it was le account of safety. The roof was wretched, and it was foun sufficient cogging material could not be procured to co place (the seam being about 12 feet thick at that point). were afraid of accidents, and for that reason the pillar wa This soft coal had been found in other portions of the D seam, and it had with difficulty been removed. The seam thick, a certain amount of slack fell into the gob, and fire occurred frequently, where pillars had not been left. regard to strengthening the stoppings and preventing th from coming through them, it had been decided, in case fire showing signs of coming through, to fill in the roa to the west of the coal-pillar. The seam was practicall from gas, which had only been found in very small quan Its absence was due to the fact that the overlying seam o had been worked, and had practically drained it away.

The PRESIDENT seconded the vote of thanks to Mr. Jon his paper, and it was unanimously approved.

MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE QUEEN'S HOTEL, BARNSLEY, FEBRUARY 2CTH, 1907.

MR. J. R. R. WILSON, PRESIDENT, IN THE CHAIR.

The following gentlemen, having been duly nominated, were elected :—

MEMBERS—

Mr. WILLIAM BADGER, Mechanical Engineer, Jagersfontein Diamond Mining Company, Orange River Colony, South Africa.

Mr. JOHN HENRY GREAVES, Mining Engineer, 69, Westgate, Wakefield.

Mr. THOMAS WIGHTON HOOD, Engineer, 120, East Ferry Road, Millwall, London, E.

Mr. JOSEPH JAGGAR, Colliery Manager, Grange Moor Collieries, Flockton, Wakefield.

Mr. T. W. KEILLAR, Mining Engineer, Wortley, Leeds.

STUDENT—

Mr. NORMAN SAMUEL ROBERTS, Mining Student, Aldwarke Main Colliery, Rotherham.

Mr. R. SUTCLIFFE read the following paper on "The Importance of Scientific Mining in the Barnsley District":—

THE IMPORTANCE OF SCIENTIFIC MINING IN THE BARNSLEY DISTRICT.

By R. SUTCLIFFE.

Miners living but very few miles from this district, an knowing something of its geological features must often env those who are surrounded with so large a number of valuabl coal-seams, which would be highly prized in other district especially by those who may have happened to be connecte with the working of seams in which, if a man has a long picl blade, he has some difficulty in turning the second point to th coal when the first has become blunted. To men employe in the getting of such seams, what is considered in the Barnsle district to be a thin seam, would to them appear to be a moderatel thick one. For clearness in this paper, the writer will assume a seams under 3 feet in thickness to be " thin seams " and all sean over 3 feet to be " thick ones." In thinking over the subject (mining in the neighbourhood of Barnsley, one cannot always sa whether the thick seam bearing the name of the town has been (that great benefit to the locality which, under other circumstance it might have been. However this may be, the fact that it is bein exhausted in the neighbourhood makes it necessary for miner who live in the town, to travel farther afield in order to reac their daily work. As the nearest collieries, now at work, becom worked out, if the thinner seams continue to be neglected, th daily journey of the miner must increase unless he moves int the country; and, as human endurance is limited, it follow that the miner's power or capacity for useful or productive wor will be proportionately reduced. A good service of trains ma exist to convey the workmen to and from their work; but wai ing, even for a short time, for a train to move so starves the body especially after a day's work in a warm mine, that it is questior able whether this train-accommodation is altogether to be desirec Until recently, however, these disadvantages were probabl unavoidable, owing to a great extent to the inability of th

ordinary miner who has served a large portion of his life in a thick seam to adapt himself to the conditions of work in a thin one, and to the length of time required for him to reach that degree of efficiency which would enable him to earn a fairly good day's wage in the latter. Of course, it follows that the sons would go with the father, and also become expert in the work of the thick seam only. If this be so, it will easily be seen that the prospect of utilizing the thin seams under and around Barnsley in the early future is not very promising, unless improved methods of working are adopted. In addition to this, the difficulties of the colliery-owner in utilizing thin seams cannot be ignored; because many departures must be made from the methods adopted in getting thick seams:—(1) The royalty-rent payable to the landlord should be much more than proportionately lower than that for the thick seam—a fact not always readily recognized by the landlord or his agents. (2) If the colliery-owner were not doing very well out of his thick coal, he could hardly expect to improve his position by embarking in the work of a thin one; while, if he was doing well out of his thick one, he would naturally "let well alone," especially as he would have to meet the royalty question just referred to, with, perhaps, the expiration of his lease also in view. (3) He would have to procure plant, corves, etc., suitable for thin seams, and work these while his plant, suitable for the thick seam, might be lying idle.

When it is remembered that the total thickness of coal underlying Barnsley, in the several beds which are known to be of a workable thickness, exceeds 40 feet, it seems difficult to understand why the three partners in the business could not come to a mutually beneficial understanding and unlock this vast amount of wealth, instead of letting the grand and fascinating industry of coal-mining glide, slowly it may be, away from the town. From the landlord's point of view, one would have thought that the proverbial half-loaf would be better than no bread, especially as the working of thin seams seldom, if ever, injures the surface in uneven country. Colliery-owners, too, often have shafts sunk through thin seams, which, if away from the close proximity of the thick coal-seam for which the shafts were originally sunk, would be of very considerable value; while the workmen, even if they were obliged to take rather less wages, would find a great advantage in having their work within

easy distance from their place of abode, and consequently would have more time to spend at their homes for rest and recreation as well as being able to avoid the disadvantages of either long walks or train-journeys to or from work.

Under these circumstances, then, it is perhaps worth while to enquire how far it is feasible to turn some of the thin seams which abound in the neighbourhood to account. These, if only situated a few miles distant from Barnsley, would be of much importance, if not of great value. In order to show that many of the thin seams in the district are of importance to the three parties referred to, it is only necessary to say that, within 8 or 10 miles of Barnsley, seams not more than 18 inches thick are being worked, and are at least paying their way under careful management, even without the mechanical aids obtainable at the present time. And this is being accomplished even where the cost is greatly increased by a charge of at least 8d. per foot for the ripping of gates 36 to 60 feet apart, and by the payment of a high rate for tramming (owing to the almost universal use of small corves in these thin seams). In some districts, for instance, in parts of Scotland and Ireland, it is customary to cast the coal to the gate-side in order that it may be filled into large-sized corves; but in West Yorkshire the tubs are taken through the working-faces even in thin seams, with the result that corves which will hold only 3 cwts. of coal are frequently used. And it is not uncommon to see a miner, lying on his back and wedging himself between floor and roof, push a corf out of some difficult position with his feet. Under such circumstances, it is impossible to get large coal into a corf.

The majority of the seams around Barnsley, however, are not thin enough to experience these disadvantages; as many of them, such as the Woodmoor, Summer, Abdy, Kent Thick and Beamshaw seams (all overlying the Barnsley seam) approach 3 feet in thickness. All these seams have the advantage of being passed through at various places by sinkings to the Barnsley seam; and consequently they should be comparatively free from water. Below the Barnsley seam, the Swallow-wood, Lidget, Thorncliffe Thin, Swilly and Silkstone Four-feet, all thin seams according to the writer's definition, are pierced by pits in the vicinity sunk to the Silkstone seam. In this list the writer has omitted the Parkgate seam, as he does not class it amongst the

dross" or "lime coal," which is invariably cast into the when there is room for it. Seeing, therefore, that so many seams are already passed through in this populous neighbourl by shafts, it seems a pity that so little effort is being made in them, even though some of the pits have been abandoned use the thick seams have been worked out.

In this rapid survey of the subject, it has been shewn that nerly much could be said for leaving the working of these ns, for the time being, in abeyance. This, however, is no ger so, because appliances are quickly being matured and fected by practice, such as will enable the thinner seams either e got concurrently with the thicker ones (where the latter still unexhausted), or through the abandoned shafts which e pierced them. Had capital to be found to sink pits to the ner seams alone, there would be some excuse for not troubling ut them while the thick ones lasted; but, where shafts already t, it seems strange that so little effort is made to get them.

It may, however, be almost taken for granted that, when the seams are worked, coal-cutters will be employed to under-cut n, and conveyors used to put the coal into corves in the ways or pass-byes, very few of which will be employed or uired. In this way, manual labour can be employed in the laborious operations of coal-getting, such as operating hines, placing the coal on face-conveyors, timbering, etc., le machinery will be adopted to do all the other work. In way only will it be possible to work thin seams on anything

by hand-labour, it was necessary to rip or make gateways every 36 to 60 feet of face. Now, with conveyors at the face, distance between the gateways need not be less than 600 feet, a the main gateways may be 1,000 or 1,200 feet apart, so t every gateway may be, and possibly will be, an engineplane p ducing several hundred tons of coal per day. In many w this, in itself, is a very great benefit in working any mine at present time. The fact that 75 per cent. of the gateways are off saves the cost of making such gateways, of the da examination of this proportion, and of the rails, sleepers, na ventilation and general repairs. The deputy, being relieved fr the examination and care of 75 per cent. of the gateways, bestow more time on the coal-face, and on getting out his wo which in itself is often of much importance. Again, the cutting of so many gateways along the face is of importance where c cutters are used, because where a large number of gateways e there is great difficulty in keeping the gate-ends clear and finding room for the débris produced by cutting, which accu lates between the pack-walls and the coal-face—often leaving small a space for expeditious working, and sometimes bury timber which would otherwise have been withdrawn.

All these advantages, however, are small compared with great saving in labour. The getting of empty tubs into a c face, filling them there, and getting them out of the face and to the gate-rails when full, is neither light nor pleasant w in any mine, no matter how thick the seam may be, but especially laborious work in a thin seam. It is not, therefo surprising that, when miners become even slightly acquain with the working of face-conveyors, they do not wish to retur tub-filling. Objection is sometimes raised to the use of c veyors in a seam where two or more sorts of coal are fil separately at the face; but a moment's consideration will sh that any such circumstance need not be considered detrimen to the working of them, provided that they are worked system cally. At present, the different kinds must be sent separately by first filling one or more corves with kind of coal, and then one or more corves with the other ki The same rule holds good in loading the conveyors: the o difference being that, with hand-filling, each man may fill whi ever kind of coal he wishes, irrespective of the kind which oth

may be filling; while, with a conveyor, every filler must load the same kind of coal at the same time, and when a change is made from one kind to another, no filler must fill the new kind until the whole of the first quality on the conveyor has passed him. This will cause very little inconvenience, as the fillers, being in touch with one another, can readily agree at what time the change from one kind of coal to another shall take place, and can arrange that the attendant at the head of the conveyor shall change the corves at that time. The fact that a corf may not be full at the time when the change is made may appear to present a difficulty, but this is more apparent than real. Flat-sheets will doubtless be used in connection with conveyors, and a partly-filled tub can easily be laid aside and its filling completed as soon as the kind of coal that it contains is again sent over the conveyor.

Whilst the conveyor, for many reasons, seems to be the natural complement of the coal-cutter, it is also applicable for use in hand-holed faces where a good or fairly good roof exists; and it will probably revolutionize the getting of coal, even in thick seams, where a good length of face can be cut. In such a face, the conveyor may be fixed, say, 4 feet from the coal, to enable the cutting machine to remain in any part of the face during the filling of the coal, or even to cut the coal while coal in other portions of the face is being filled. This is an advantage, the effects of which may be far-reaching. It certainly overcomes the inconvenience of compelling the machine to cut exactly from stable to stable, and no more, in a day: thus doing away with stables in or along the face, and allowing the cut to be made gradually inward; or the machine may be pushed into position by jacks or otherwise while cutting. Further, a sufficient number of machines can be put on a face, to cut any length of coal that may be desired. Such a face, say, 1,200 feet in length, can be dealt with by two conveyors delivering on to a gate-conveyor; and such a face, 5 feet thick, with a 5 feet undercut would, in round numbers, produce 1,000 tons or 2,000 corves, each holding 10 cwts. To deal with this number of tubs in 8 hours would require 4 tubs to be filled per minute. This, however, is only the capacity of one face-conveyor, which not only can fill, but has filled similar corves at the rate of one in 15 seconds.

The writer, however, is dealing with thin seams, and probably only 400 tons of coal per day would be obtained from a face

1,200 feet long. This quantity can easily be dealt with by two conveyors, each 600 feet long, delivering on to a gate-conveyor carrying the coal to the corves at the pass-byes. The latter conveyor may be of any length and capacity. It is not necessary to refer to the smaller number of corves required under this system.

It will, of course, be readily understood that the pass-bye will be placed at the delivery-end of the conveyor, and it will be easily readily conceived that, to deal with even 400 tons per shift in a passage or gateway with either horse or hand-labour, is no easy matter; while it is inconvenient to have to keep shifting up the main-rope haulage-wheel at short intervals. A small main-and-tail-rope hauling-engine could, however, be placed in the main pass-bye at the return-wheel, with a small return-wheel at the conveyor-end for drawing the corves between the conveyor and the engineplane or main pass-bye.

The writer has designed a small hauling-engine to deal with this class of work, which, he thinks, will find favour with colliery managers even for more extended use. It is suitable for endless-rope haulage; and the rope, contained on two drums, can be readily extended as the gateway lengthens. It can be operated by compressed air, electricity, or from the return-wheel shaft of the main haulage-rope.

It has been already stated that, where hand-work prevails, small tubs must be provided if thick and thin seams are to be worked simultaneously; but, where conveyors are used, this is unnecessary, as the large tubs may be employed in even the thinnest seams. Every colliery manager knows the trouble incurred at a colliery when tubs of various sizes are used concurrently.

Thirty years ago, the writer used coal-cutting machines in a seam 18 inches thick, in the largest colliery in Ireland, where the measures dipped 1 in 5. Sledges were used at the face, the gateways were spaced 135 feet apart, and the tubs were filled in the gateways. As a consequence, it was found that, if the average selling price of the coal could be maintained at 7s. 6d. per ton, a fair profit could be made. Unfortunately, that price was not obtained, otherwise the colliery, in all probability, would be working still. The demand did not reach one-fourth of that expected: consequently the coal-cutters were taken out, and were afterwards brought to England, and the writer believes that some of them are working in Yorkshire to this day after thirty years'

service. In Yorkshire, the writer has worked coal-seams, with coal-cutters, down to 15 inches in thickness at a profit, and in the Barnsley district, he is interested in coal-cutters working the Abdy seam, which he has no hesitation in saying is admirably suited for such machines. Seeing, then, that the use of machinery for getting coal is no longer problematical, and that its application to the thin seams of this district is quite feasible, the wonder is that coal-cutting machines have not been more largely used. Notwithstanding the difficulties already referred to, it is certain that, in the absence of thick seams, the thin seams found in the district would become valuable, and if worked would give employment to a large number of people as well as to coal-cutters.

It is, at least, of some interest to the district generally that an industry so long established, and of such importance as coal-mining, should not be allowed to decline even slowly; and, if this is to be prevented, the question of utilizing some of the seams now lying neglected must be considered in earnest. Fortunately, circumstances in the neighbourhood are unusually favourable for this, owing to the numerous abandoned shafts by means of which access can be obtained to the thinner seams that have been entirely ignored by the former proprietors, and now lie close to these shafts waiting to be operated by some enterprizing capitalist.

The writer does not forget that thin seams in the Barnsley district have, from time to time, been broken into, and that here and there attempts have been made to turn them to account, but with little success. Such attempts, however, were not made either in the manner or by the means which were likely to be successful. In order to achieve success under present conditions, thoroughly organized, systematic, and energetic management is of the first importance. To ensure this, the staff should consist of men knowing the requirements necessary for the successful working of up-to-date methods and machinery. The courtesy and fraternity at present prevailing amongst Yorkshire coal-owners and managers greatly facilitates the acquisition of these attributes or qualities by allowing friendly visits by interested officials to neighbouring collieries; and the writer hopes that this benevolent spirit, with the good that results from the mutual interchange of ideas and suggestions, will long prevail.

Of all people, the working miners of the district should be

particularly interested in the opening out of thin seams. The writer has already remarked that it is doubtful whether the Barnsley seam is of that great benefit which it might have been under other circumstances, because its extreme value made nearly all the other seams appear almost valueless; but, from the workers' point of view, he thinks that the thinner seams ought to be considered of greater importance, because more labour must be employed to produce the same amount of coal.

Even with modern machinery and appliances, it can hardly be expected that a man in a seam 3 feet thick can get coal as quickly as in a seam 10 feet thick. Under these circumstances, then, can the aid of the miner be counted on, in developing the numerous thin seams which are found in the district? The writer has no misgivings on the matter, and unhesitatingly says yes, if properly dealt with. The writer has been amongst the Barnsley miners, and knows many of them, and he has no hesitation in saying that there are quite as many real heroes amongst them as amongst any other miners in the kingdom. No person can doubt that miners all over our land are real heroes in case of need, when the numerous calamities which have occurred within recent times are recalled. In proof of this statement, reference need only be made to one case: not many miles from Barnsley an accident occurred in a shaft, and several men were precipitated from a scaffolding into the pit-bottom. When the rescuers got down they found one man hanging head downwards on a crook, which had caught in one of his boots. This man knew well enough that if his bootlace gave way it was instant death for him, still he implored the rescuers to hasten to his mates in the bottom, and relieve them before releasing him from his dangerous position. Should not such heroism be printed in letters of gold? How prevalent such cases are amongst miners in times of need! Can it be doubted then that such men will try to assist in all legitimate enterprise for the advancement of their calling, and the good of all around them?

Although the writer has not mentioned any of the seams of the Lower Coal-measures (those below the Silkstone seam), it is not because he attaches no importance to their value, but because it is quite unnecessary to go to the expense of opening out and working the deeper seams when so many exist in the district at much shallower depths. It is well known, however, that the

lower seams play an important part in a large area of the West Yorkshire coal-field, where the Beeston and Black Bed seams are extensively worked. Below these again are the Halifax seams; these seams are even of greater extent, reaching to the far south of Ireland, except where they have become denuded, and they enter largely into the production of coal in Lancashire as the Mountain mines.

The PRESIDENT (Mr. J. R. R. Wilson, H.M. Inspector of Mines) said that the members would agree with Mr. Sutcliffe, when he stated that, to achieve success, "thoroughly organized, systematic, and energetic management is of the first importance," whether they worked coal at Barnsley or in any other part of the country. The members were well prepared to admit that amongst miners, as a class, there were real heroes; but he questioned whether a man, although he would hang down a shaft at the risk of his life, would go to work in a seam, 2 feet 6 inches thick, if he had the chance of working in a seam 6 feet thick. He proposed that the thanks of the members be given to Mr. Sutcliffe for his paper.

Mr. E. W. THIRKELL, in seconding the vote of thanks, said that a paper was written by the late Mr. Robert Millar, sixteen or seventeen years ago, on "The Coal-field adjoining Barnsley,"* and it would be interesting to compare the two papers. Mr. Millar said that he did not aim at a very great deal, but he hoped to cause people to think; and he (Mr. Thirkell) agreed that, if they could get people to think, particularly in matters of mining, they would be doing good. Mr. Sutcliffe would cause people to think, if they only read the title of his paper, because some engineers thought that if anybody knew anything at all about getting coal, they did at Barnsley, and also how to get it in a scientific way. But with the Barnsley seam, engineers did not need to trouble very much about science in the olden days.

Regarding the subject of Mr. Sutcliffe's paper, the situation was hardly that the seams under Barnsley were not valuable, but that the necessity for working them had not yet arisen. Barnsley engineers were quite as shrewd as others, and they would not let valuable mineral property be lost for ever as

* *Trans. Inst. M. E.*, 1890, vol. ii., page 7.

stated by Mr. Millar in his paper. Mr. Sutcliffe and everybod else could rest assured that Barnsley engineers knew full we that it was there, and that they were only waiting for the prope time to work it. Respecting the statement that appliances wer being improved and perfected, he (Mr. Thirkell) said that wa so, but they were not yet perfect, and when they were, Barnsle engineers would bring them into play in working the thinne seams. He quite agreed that it would not have to be done in half-hearted way, nor would it be advisable for somebody i prosperous times to start to work a thin seam, then leave it an probably ruin it and himself, and he also agreed with what wa said regarding the management, which must be "thoroughl organized, systematic and energetic."

Officials and workmen must be properly educated in the use o the machinery to be applied, and trained men accustomed to th work would be required. Machinery for coal-cutting, convey ing, etc., required skilled men, who, by long practice, were abl to avail themselves of every advantage, and, notwithstandin Mr. Sutcliffe's belief that the miners in the district could b counted upon to develop the thin seams ("if properly dealt with, whatever that meant), it was no disparagement to a Barnsle collier to doubt his ability to compete successfully with a traine thin-coal miner, in working thin seams. There was no disputin the fact that coal-values were relative, and unless they could pu the thin seams on the market at a cheaper rate than the Barnsle seam, they would prefer to have the Barnsley seam; and not onl that, but the difference in price between the Barnsley and othe seams would have to be such as would equalize at least all th economies brought about by the use of elaborate machinery, bot aboveground and belowground. He (Mr. Thirkell) believed tha with the aid of machinery, seams which were regarded as worth less now would, in time to come, be worked. Several of th seams contained thin bands of dirt, which made it impossible t sell the coal as large coal; but, when crushed, washed and sized it could be utilized for coke-making and for furnaces speciall made for firing by small coal. He (Mr. Thirkell) was sure tha these seams would be worked when the time came: a livin was now made out of seams that our fathers considered worthless and the recovery of what formerly was taken as waste or unpro ductive, was now the question of the day. The members coul

see what was being done in this respect in gas-works, soap-works, bye-product plants, etc., and in years to come, those who came after us would do as we were doing now.

In Mr. Millar's paper, which dealt principally with the seams below the Barnsley bed, reference was made to the difficulties to be met with in dealing with the water. These difficulties were far greater to-day than when Mr. Millar wrote his paper. The water in the old shafts probably alluded to by Mr. Sutcliffe was practically at a level with streams on the surface, and the question was one which the mining engineers of the district had long had under consideration. When they looked at the list of members, and particularly at the list of past-presidents, the members saw a list of mining engineers upon whom they could depend to cope with these difficulties and to see that the mineral wealth under Barnsley was not wasted. In early Parliamentary elections, much was said about Barnsley being the "right eye" of Yorkshire. He thought that the members could take it for granted that when the time came for the seams of which Mr. Sutcliffe had spoken to be worked, that "right eye" would be very wide open indeed.

Mr. J. L. Marshall said that he agreed with the spirit in which Mr. Sutcliffe's paper had been written, but the members were also bound to agree with Mr. Thirkell's views as to the difficulty of the present development of these thin seams. The time for their working had not yet arrived; but, when it did, he thought that the seams would be worked with the aid of coal-cutters, coal-washers and coal-conveyors. He asked whether the writer had had experience of the use of conveyors in thin seams with soft, spongy bottoms and similar tops.

Mr. H. Rhodes thought that the key of the position lay in the question of average selling-price. If the average selling-price could be maintained at 2s. or 3s. a ton more than was obtained at present, almost any seam might possibly pay to work, assuming that the wages-rate remained the same. It might be taken as certain, however, that the wages would increase as the selling-price increased. In abnormal times any seam would pay, but such a subject as this could only be dealt with on a normal basis; and, when the thin seams had to be worked in competition with the thicker seams, in these days it would be impossible to

work them successfully unless they were so specially situated a to obtain some exceptional advantages in the selling-price. If Mr. Sutcliffe looked further into the matter, he would find that he was hardly correct in stating that the thin seams above the Barnsley bed would be comparatively free from water. If he (Mr. Rhodes) was not mistaken, many of them were water-logged at the present time; and, in several instances, their working has been abandoned owing to the water-difficulty.

Mr. W. Walker (H.M. Inspector of Mines) said that the statement that no thin seams were being worked in the Barnsley district was hardly correct, as thin seams were being worked at Barrow, Dodworth, and other collieries. It seemed to him very desirable that the thin seams should be worked simultaneously with the thick seams, and it would be an encouragement if royalties could be arranged on a tonnage-basis, in proportion to the thickness and qualities of the seams.

Mr. H. B. Nash said that, in 1892, he read a short paper before the Barnsley Naturalist and Scientific Society on "The Unworked Coal-seams of Barnsley and District," and he then stated that, owing to the difference in their thickness, their inferior quality and their enhanced cost of working, they could not be successfully worked in competition with the thicker and more valuable Barnsley bed. On that account their development had been comparatively slow, but sufficient had been done to show that a very valuable coal-field remained to be developed and worked, as time and circumstances warranted. He thought that statement met the whole of Mr. Sutcliffe's arguments, as the time had not arrived for the successful working of these seams When the time came, the necessary appliances would be utilized; although the experience of the last few years in the matter of these thin seams had not been such as to induce any capitalist to take them in hand.

Mr. T. W. H. Mitchell said that the miner whom Mr Sutcliffe praised so much, and who did display courage in times of stress and danger, forgot himself at such times and went to the succour of his companions; but in times of arranging price lists he went for himself as against his employer. In two or three cases, where the upper seams had been tried in pits in which the thicker seams had been nearly exhausted, wages had

been the great obstacle to successful working. In his opinion, the miners of Barnsley would have to learn to work in thinner seams, and in so doing must expect the wages to be less. The workmen ought to consider that their proportion of the development of the thinner seams was given in the lesser wages that they would accept, whilst the landlord would have to take less money for his royalty, and the owner would take his smaller profits. Mr. Marshall had referred to the working of seams with soft bottoms. He had known one or two instances where a road had been left beautifully clear at the end of a shift, but when the miner wished to return to his work he could not get in because the roof and the floor were practically meeting; and some method must be devised for dealing with that difficulty. Mr. Sutcliffe had stated that the working of thin seams would not injure the surface: unfortunately, he (Mr. Mitchell) had had a different experience in the working of a bed of clay at about the same depth from the surface as the thinner seams referred to in Mr. Sutcliffe's paper.

Mr. T. Gill said that he was afraid that some of the seams under Barnsley were not so valuable as Mr. Sutcliffe represented them to be. He knew a place in the borough of Barnsley, where the Silkstone seam was worked and it had not a very profitable section. It consisted of inferior coal, 2 inches; top coal, 1 foot 7 inches; dirt, 8 inches; coal, 4 inches; dirt, 1 foot 2 inches; and bottom coal, 9 inches. The 4 inches of coal were of very little use, as splitting it off and picking out the dirt was not worth the trouble, so that only 2 feet 4 inches of coal, together with 2 feet 4 inches of dirt, was left. It had been proved that the Silkstone seam under Barnsley deteriorated in quality as it extended eastward. Therefore, in his opinion, the Silkstone seam under Barnsley was not worth working at the present day.

Mr. R. Sutcliffe, replying to the discussion, said that his chief point was that the thin seams should be worked, rather than that the collieries, from which thick seams had been extracted, should be abandoned. He was strongly convinced that the thin seams were valuable.

Mr. N. W. Routledge's paper on "The Most Suitable Form of Guides for Cages for Winding from Deep Shafts: 1,500 Feet and Deeper," was read as follows:—

THE MOST SUITABLE FORM OF GUIDES FOR CAG FOR WINDING FROM DEEP SHAFTS: 1,500 FE AND DEEPER.*

By N. W. ROUTLEDGE.

In selecting the form of guides to be adopted in a deep sha the mining engineer is governed by many considerations. I is confined practically to two forms: the rigid and the flexib In the former class, he may have wooden guides, iron or st rails, and H or T-section girders; and in the latter, he has t choice of wire-rope or round-iron rods.

Wire-rope Guides.—The writer considers that, under ordina circumstances, wire-ropes are the best kind of guide for a de shaft. The advantages are simplicity, smooth running of t cage, little risk of derailment and long life. The disadvantag are increase of weight on the headgear, and sag or sway in t shaft, necessitating more clearance in the shaft than with rig guides.

The usual construction of guide up to 4½ inches in circu ference contains seven wires; and over this size, up to, say, inches in circumference, twelve wires are twisted together. F still larger sizes, they are made in the form of a rope, that six strands of seven thick-drawn wires are laid together. selecting the size to instal, care must be taken to make allo ance for the weight of the rope, for the weight hung on it, a for the wear of the guide.

The large wires give, as compared with an ordinary ro increased wearing surface and a longer lapse of time before t wires are worn through. The best guides are made of charco iron, but this being practically unprocurable, they are usual made of dead soft steel.

* This student's prize essay is printed in the *Transactions* at the spec request of the Council of the Midland Institute of Mining, Civil and Mechani Engineers.

Fixing the Guides.—There are several methods of fixing guides, the most usual being as follows: one end of the rope is clamped in the headgear, by a specially made clamp, AB, to suit the size of rope, and after passing through a baulk or girder, C (figs. 1 and 2, plate ii.), the rope hangs down the shaft as far as the sump. In this method of clamping the rope, it is passed through an eye-hole or baulk to give it steadiness; and a weight of, say, 5 or 6 tons to give tension, and as far as possible to prevent sway, is hung on the end. Fig. 3 (plate ii.) shows an arrangement in the sump with the attached weights. The weights are most conveniently handled when built up of a series of small blocks weighing 5 or 6 cwts. each. It is important that the weights should not be submerged in water, otherwise, their weight, and therefore their efficiency, would be decreased in proportion to the weight of water displaced. Where the sump is shallow, or not roomy, a system of levers might be adopted to decrease the size of the weight. In another arrangement, the rope is clamped in the sump, and the weight put on at the surface (fig. 4, plate ii.): this takes up all variation in length due to stretch, or difference in temperature. One weight may also be made to suffice for two ropes.

Life of Guides.—The life of the guides varies under different conditions from a few years up to 20 years. The chief factors are atmospheric conditions, whether the shaft is wet or dry, and whether there is any acid in the shaft. Any or all of these combined might cause the guides to corrode very quickly. The writer suggests a system whereby lime-water, or some other alkali, could be constantly applied to the guides to neutralize the acid.

Shoes or Runners.—Fig. 5 (plate ii.) shows an ordinary runner for rope-guides. They are made 12 or 14 times the diameter of the rope in length, and are lined with brass: the liner being renewable. The runners are bolted to the side of the cage. Rollers have been tried, but do not give satisfaction.

Position of Guides.—The position of the guides varies according to the size of the cage, and according to the local circumstances met with in the shaft. The writer favours the use of

four guide-ropes to each cage, fixed practically at the corn with rubber ropes (afterwards described) between the cages (1 6, plate ii.). These are similar in construction to the guide-rop and are fixed in the same manner at bank and in the sump. Th are not in any way connected to the cages, but are simply used a buffer between the cages at meetings and for the cages to r against when winding. Blocks of wood are attached to t cages, so as to make sliding contact with these ropes.

Clearance.—The writer considers that it is of more importa to have clearance between the cage and the shaft-side th between the cages at meetings. Where rubber ropes are us there is no danger of collision; but, should the cage catch t shaft-side, irreparable damage may be done. A clearance about 18 inches may be left between the cage and the sha side, but the writer would let the cages make the contact w the rubber ropes as nearly constant as possible.

Vibration and Sway.—The vibration of the ropes produ swaying of the cages, and it is impossible to apply sufficie tension on the guides to obviate this disadvantage. Mr. Char Snow, at South Kirkby colliery, uses a very ingenious arran ment, which has proved satisfactory. He has, by varying t weights, tuned up the ropes to different tensions; thereby, t vibrations producing the sway are of different periods, and te to counterbalance each other.

Extra Weight on Headgear.—The weight of the guid together with that of the weights hanging at their ends, appl an additional stress on the headgear, which must, in consequen be specially designed to resist safely the increase of weight. an example: eight guide-ropes, 4½ inches in circumference, 1,! feet long (weighing 6¾ pounds per foot), with eight weights o tons each, puts a weight of 75½ tons on the headgear. With t rubber ropes, similar in size, the weight would be increased to tons. It will at once be recognized that this is a tremendous crease, when compared with a headgear which has only to ca the weight of the cages, etc.

The writer suggests that some member should draw a pa lelogram of forces, and find the position of the backstay on

headgear. If the weight of the guides, etc., be included, the resultant is at a very singular angle to apply a backstay.

Arrangement of Ropes.—Fig. 6 (plate ii.) shows an arrangement for rope-guides in conjunction with rubber ropes, and gives the writer's ideas with regard to their positions for deep and rapid winding. Four guide-ropes, A, are applied to each cage, B; two rubber ropes, C, are placed between the cages; and two wooden blocks, D, engage the rubber ropes. The limit of clearance might be taken at 8 inches between the sides of the cages, and at 18 inches between the corners of the cages and the shaft-side.

The guides should be kept well lubricated; and attention to this item will prolong their life and reduce friction.

Mr. A. J. KENNEDY's paper on "The Most Suitable Form of Guides for Cages for Winding from Deep Shafts: 1,500 Feet and Deeper," was read as follows:—

THE MOST SUITABLE FORM OF GUIDES FOR C FOR WINDING FROM DEEP SHAFTS: 1,500 AND DEEPER.*

By A. J. KENNEDY.

I.—Introduction.

When dealing with winding or any other question r to the practical working of a colliery, three main conside are to be taken into account: namely, safety, efficien economy; and it is essential that all three conditions shc satisfied by the best form of guide for deep shafts. Tl two naturally go together: for, in most instances, where perfect safety has been realized, the standard of efficien been as high. Therefore, when undertaking any kind o wherein the safety of either men or animals is affected, th conditions must always be maintained, even in the f economy if necessary. But economical working can ge be realized without loss of either safety or efficiency, if means are used.

In order to discuss this particular question in an ea simple manner, the best plan will be to take a practical e such as the following:—It is desired to wind 2,000 tons depth of 2,400 feet in 8 hours. All other considerations, s the size of shafts, etc., are left to the discretion of the en

This big tonnage will undoubtedly necessitate the sinl a shaft of large diameter. Let it be supposed that a about 18 or 20 feet in diameter, will be required, varying according to the kind of conductor employed. Therefc engineer is faced with the problem "What is the most s form of guides for cages for winding from a shaft 2,4(

* This student's prize essay is printed in the *Transactions* at th request of the Council of the Midland Institute of Mining, Civil and M Engineers.

nstruction of the cage. The cage adopted is shown in and 2 (plate iii.). It will be seen that it is of modern ıction, and made for carrying a counterbalance-rope. The ages of this device are now fully recognized, and will be ɔred later.

II.—Wooden Guides.

ɔ first thing to be considered is the position of the guides ɔlation to the cage. The complete arrangement is shown 3 (plate iii.) with two guides, A, placed at each end of ge, B, on account of its width. This arrangement mak-s ssary to have extra guides, C, at the surface and at the tom, because the shaft-guides must terminate before ıg the landings in order to clear the ends of the cage.

ɔ necessary amount of clearance between the cages, when uides are used, is obviously small, since little or no oscilla- n take place. In practice it varies from 3 to 12 inches, this case, the clearance is 9 inches.

ɔ cage-shoes, made of cast steel, are bolted to the ends ɔage, on the top and bottom hoops (figs. 4 and 5, plate iii.).

ɔ method of fixing wooden conductors together and to the s is shown in figs. 6 and 7 (plate iii.).

order to ensure perfect safety with wooden guides, the used must be of the best quality, free from knots, of t grain, and able to take up a large amount of lubricant

doubt correctly according to their own experience, that wo guides only last from two to five years. But this period ca extended to at least 15 to 20 years if the guides are gre thoroughly and regularly, every fortnight.

With regard to economy, the following is an approxi estimate of the cost of fitting up a shaft, 18 feet in diam and 2,400 feet deep, with conductors, etc., as shown in figs. 5, 6 and 7 (plate iii.):—

	£	s.	d.	£	s.
Materials:					
Buntons, 8,400 lineal feet at 4¼d. per foot ...	148	15	0		
Stays, 600 cubic feet at 1s. 3d. per cubic foot ...	37	10	0		
Conductors, 4,800 cubic feet at 1s. 3d. per cubic foot	300	0	0		
10 per cent. for joining pieces	48	0	0		
Cast-iron boxes, 27 tons at £8 per ton	216	0	0		
				750	5
Labour:					
Sawing, planing and fitting buntons, etc. ...	250	0	0		
Sawing, planing and fitting conductors	400	0	0		
				650	0
Total				£1,400	5

III.—Steel-rail Guides.

Steel-rail guides are largely used on the Continent, but this country they have not found quite so much favour. steel-rail guides were used in the shaft already mentioned, t following arrangement might be adopted: Four rail guides, weighing 20 pounds per foot, placed, two at either side of t cage, B. In the middle, they are clamped to steel joists, and at the sides to cast-iron sleepers, D, bolted to wood buntons, E. The vertical distance between the centre of t joists or of the buntons is 10 feet; and the rails, forming t guides, are in lengths of 30 feet. This is the only arrangeme permissible, since rail guides are not suitable for fixing at t ends of the cage. The arrangement is shown in figs. 8, 9, 1 11, 12, 13, 14 and 15 (plate iii.).

This type of guide lasts about fifteen years; but, in sor cases, it has been known to fail at the web in a shorter tim owing to the wear of the shoes at this point.

The approximate cost for fitting a shaft, 18 feet in diamet and 2,400 feet deep, is as follows:—

	£	s.	d.	£	s.	d.
Materials:						
Rails, 171·4 tons at £6 per ton	1,028	8	0			
Joists, 8 inches by 3 inches, 15·6 tons at £6 per ton	93	12	0			
Wooden buntons, 6 inches square, 400 cubic feet at 1s. 3d. per cubic foot	25	0	0			
Cast-iron sleepers, 3 tons at £9 per ton ...	27	0	0			
5 per cent. for waste	58	0	0			
				1,232	0	0
Labour:						
Cutting and fitting joists, buntons, etc. ...	500	0	0			
Fitting conductors	400	0	0			
				900	0	0
Total				£2,132	0	0

IV.—Rope Guides.

This system is very popular amongst British mining engineers. At first sight the cost appears to be very low, but this is by no means the case when everything is taken into account.

Owing to the flexible nature of the guide there is a large amount of oscillation. This can be reduced to a minimum by using a tail rope under the cages; and, in some cases, this device has been found to be absolutely necessary to prevent bumping at meetings, even when curtain ropes are in use. But even with a tail rope, in a shaft 2,400 feet deep, at least 18 inches of clearance between the cages, and 12 inches between the cages and the sides of the shaft must be allowed. This necessitates the sinking of a shaft 20 feet in diameter. The difference in cost for this larger shaft will be at least £1 per foot, which must be added to the cost of fitting rope guides.

The advantages claimed for this system are:—(1) Easy fitting up and working; (2) freedom of expansion or contraction; (3) a clear shaft; (4) lessened first cost; and (5) longer life than any other type of guide. The first three advantages are undoubtedly obtained, but the fourth is quite incorrect, as will be shown later.

There is a great diversity of opinion with regard to the life of a rope guide. Instances are quoted where rope guides have lasted over 30 years. But they are the exception, and not the rule, as the writer discovered when making inquiries amongst enginewrights who had had the handling of them. They stated that 5 to 10 years was the average life of a rope guide.

Figs. 16, 17, 18, 19, 20, 21 and 22 (plate iii.) show the det of the various arrangements.

The estimated cost of fitting a shaft, 20 feet in diameter 2,400 feet deep, with rope guides, is as follows:—

	£ s. d.	£ s.
Materials:		
Ropes, 42·4 tons at £30 per ton	1,272 0 0	
Cast-iron weights, 24 tons at £8 per ton ...	192 0 0	
		1,464 0
Labour:		
Fitting guides, etc.		50 0
Sinking:		
Extra cost of sinking at £1 per foot		2,400 0
Total		£3,914 0

V.—Conclusions.

As each system has now been considered, it only remain the best to be selected.

So far as safety is concerned, all three methods have laid out in such a way that the maximum safety has obtained in each case, so that it may be justly and correctly that they are all as safe as it is possible for anything to be, that no comparison can be formed on this point.

The next point to be considered is the relative effici Summed up as briefly as possible, the life of each system follows:—(1) Wooden guides, 15 to 20 years; (2) stee guides, 15 to 20 years; and (3) rope guides, 5 to 10 years. shows that wooden or steel-rail guides are the most econon so far as efficiency is concerned.

The relative costs are as follow:—(1) Wooden gu £1,400; (2) steel-rail guides, £2,132; and (3) rope guides, £3 From these figures it is proved that wooden guides are b the most economical.

Therefore, according to the general principle of analys regards safety, all three systems are equal in merit; as re efficiency, wooden or steel-rail guides excel; and wo guides are the cheapest. So that, to sum up the situation few words, pitchpine guides are, by reason of their sa efficiency and economy, "the most suitable form of guide cages for winding from deep shafts: 1,500 feet and deeper

Mr. Herbert Perkin (Leeds) wrote that, in dealing with the construction of rope guides, Mr. Routledge did not mention the wellknown locked-coil guide rope, which seemed to be the most suitable as presenting a perfectly uniform wearing surface. A good form of clamp (figs. 23 and 24) was in use at the Shelton Coal and Iron Company, Limited's deep pit at Hanley, where rope guides were in use in a shaft 2,550 feet deep. It consisted of a rectangular block-forging in which a slot was cut, and two wedges, gripping the rope, were fitted into the slot. Above this, with a slight gap in between, two or three clamps of the ordinary bolted type were fixed on the rope, the gap being used to indicate whether any slip was taking place. In the sump, the method of attaching the weights was simply the reverse of the arrangement used in the headgear. This method had been found eminently satisfactory. With regard to the weights hung upon the conductors,

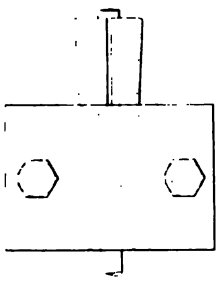

Fig. 23. Side Elevation of Clamp.

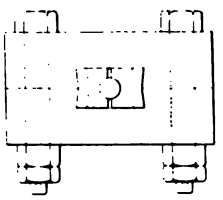

Fig. 24.—Plan of Clamp. Scale, 1 Foot to 1 Inch.

the limit, of course, was reached when further increase would dangerously lower the factor of safety: this should not be below 5, that was, the attached weights together with the weight of the hanging rope should not be more than one-fifth of the breaking load. The clearance of 18 inches between the cage-corners and the shaft-wall was certainly most important, because of the possibility of a bulging of the shaft taking place, and 15 inches between the centre guides were ample.

He (Mr. Perkin) could not agree with Mr. Kennedy's conclusions that wooden guides were either as safe, as efficient, or as economical as rope guides for great depths. It seemed a very dangerous plan to fill a downcast shaft with timber, especially if electric cables were taken down the pit. The bolted joints were also a source of danger. Mr. Kennedy's addition of

£1 per foot for the extra cost of sinking a shaft, 20 feet i diameter instead of 18 feet, overlooked the important fact of th largely increased area obtained. It was probable that in a shaf 18 feet in diameter, fitted with wooden guides, the effecti area would be reduced by 8 or 10 per cent., owing to bunton For equal quantities of air, therefore, there would be a ver considerable saving in the power required for ventilation i the case of a shaft 20 feet in diameter. If non-twisting rop were used there would be very little oscillation, and the add tion of a tail rope was a profitable investment, apart altogeth from any steadying qualities that it might have. The gre disadvantage of rigid guides was their liability to cause extr friction by being thrown out of plumb if there was a sligl movement of the shaft.

Mr. M. H. Habershon said that members, who had exper ence of winding large quantities of coal with wooden guide would agree that the cost of repairing was excessive, and th the conclusion at which Mr. Kennedy arrived as to their econom was not correct.

Mr. W. Walker (H.M. Inspector of Mines) said that appeared from Mr. Routledge's paper, that he had taken as minimum a shaft 20 feet in diameter for wire-rope guides; bu in the case of South Kirkby colliery the shaft was only 15 feet i diameter, and the clearance between the cages at meetings wa as little as 6 or 8 inches. The shaft was 2,130 feet deep, and th weight at the bottom was much in excess of the figures given b Mr. Routledge. This weight was a serious consideration so fa as the headgear was concerned, but the running was even, an there was no difficulty in any other way. He thought that t distance given between the buntons in both papers was too gre as an accident had occurred from this cause in his mines-inspe tion district last year with rail guides. One of the rails brol and the cage became free and collided with the descending ca at meetings. He could not agree with Mr. Kennedy's concl sions that wooden guides were the safest or even the mo economical. Taking the speed at which the cages ran at Cade colliery, about 72 feet per second, when men were being rais or lowered, he should not like to be in the cage if the guides we made of wood. The shoes used in connection with rail guid

were better and safer if they extended over the full length of the cage, as at Cadeby colliery; and, if a rail broke, there was not then so much chance of the cage getting out of the guides.

Mr. J. J. ELEY said that he was, at the present time, substituting rope guides for wooden guides, and the cost of maintenance and repairs of wooden guides was very high in comparison with wire-rope conductors.

Mr. A. T. THOMSON said that he had experience of three kinds of guides. Wooden guides were a source of continual expense, as some lengths were always being changed; he had some wire-rope guides which had been in use for thirty-three years, and they were still in splendid condition; and he had had a rather unpleasant experience with rail guides. He much preferred the use of wire-rope guides.

Mr. H. RHODES said that, over a period of thirteen years, the number of stoppages at six shafts, fitted with wire-rope conductors and varying in depth from 1,200 to 1,800 feet, was considerably less than at a similar number of shafts, fitted with wooden conductors and varying in depth from 360 to 1,200 feet.

Mr. R. PURDY said that he could not agree with Mr. Kennedy that wooden conductors were either the best or even the cheapest. He knew a shaft, over 1,800 feet deep, where wooden conductors, 7 inches by 5 inches, were in use. As they were occasionally broken and caused stoppages and damage, they were replaced by wire guides; and the alteration proved a great advantage, and soon paid for the cost of changing. He thought that Mr. Kennedy's estimate of 1s. 3d. per cubic foot was very low for pitchpine suitable for conductors, and he (Mr. Purdy) was paying nearly 2s. per cubic foot.

Mr. Routledge referred to vibration or sway, regarding which he (Mr. Purdy) thought that the whip or swing of guide-ropes in a shaft was not so much the fault of the guides as of the cage not being properly level and balanced at the commencement. Winding a cage, 9 or 11 feet long, 4 feet wide and 12 or 15 feet high, was like trying to balance a brick on its edge. If the cage were lifted 6 inches at one end before being raised at the other, the whip set up in the winding-rope would be transmitted to the guide ropes and the cage would be in danger of striking the shaft-sides or of coming into contact with the opposite cage when pass-

ing. To prevent this whip, the four carrying chains should fitted with left-hand and right-hand screws, and the cage sh be hung in perfect balance from each corner. The props at surface and the buffers at the bottom should be made perfe level to receive the cage, so that when it was raised by the w ing-engine, there should be no tilting motion at the comencem If the balance and levelling were properly attended to, the of accidents would be materially reduced.

Mr. H. Baddeley said that in the case of two shaft North Staffordshire the use of a balance-rope had consider reduced the oscillation of the cages. Each shaft was over 2 feet deep, one shaft being 14 feet in diameter for some depth, it was then belled out to 20 feet in diameter. A flat balance- was used in both cases, and the oscillations, as stated before, very little; and, although there was not a great space betv the cages and the shaft-sides, everything seemed to work s factorily. The use of a flat balance-rope was somewhat novelty to him (Mr. Baddeley) and he was interested with satisfactory way in which it was working. No pulley or ca was required in the pit-bottom, and the rope simply form curve below the sump-boards. He observed that the estimated given by Mr. Kennedy for pitchpine was too low, and tha would like to sell wire-rope guides at the prices named in Kennedy's estimate.

Mr. C. H. Elliott (Wombwell Main colliery) said that winding shaft at Wombwell Main colliery was 1,500 feet d the upper 660 feet being 11½ feet, and the remainder 13½ in diameter. Six corves were carried on three decks; the w ing-ropes were locked-coil, $1\frac{5}{16}$ inches in diameter; and the c were provided with a balance-rope, which passed round a pu in the sump. Formerly, each cage ran on four wire-rope gui 1½ inches in diameter, two guides being placed at either side, the corners of the cages. This arrangement gave a clearanc 12 inches, but the cages caught the sides occasionally, whe the smaller portion of the shaft. This difficulty had been suc fully overcome by suspending two separating guides, eac inches in diameter, down the centre of the shaft, bringing cages close up to them, and at the same time adopting t guides, all placed at the outer sides of the cages, for the

which were formerly placed near each corner. Each cage was fitted with a rubbing piece of soft steel, which could be changed when worn out. This arrangement had now been at work for seven years without the slightest hitch, and the cage ran very smoothly. The output was 1,500 tons in 10 hours, a draw being made in 50 seconds, with an average cage-speed of 30 feet per second.

Mr. G. A. Longden (Pleasley) wrote that the two shafts at Pleasley colliery, sunk to the Top Hard coal-seam in 1877, were 14½ feet in diameter and 1,560 feet deep. The downcast-shaft only was fitted with wooden guides; and, in 1888, the double-decked cages, with two trams on each deck, were winding to their full capacity. In order to obtain an increased quantity of coal, the upcast-shaft was fitted up in 1888 with cages holding one tram on a deck: at first two-decked and later three-decked cages were used, decking at the pit-top and the pit-bottom. This arrangement sufficed for eleven years; and, in 1899, it was decided to erect a new winding-engine, headgear and boilers to work at a pressure of 100 pounds per square inch, and to fit cages in the upcast-shaft similar to those used in the downcast-shaft with simultaneous changing of the decks.

Rope Guides.—The question of conductors at the upcast-shaft was carefully considered, and iron-rope guides were adopted as being the safest and cheapest, with less friction in the shaft both for the cages and for the ventilation, which must not be overlooked in small shafts, 14½ feet in diameter. There were two loose rope guides, 2 inches in diameter between the cages; oaken rubbers were bolted to the cages to prevent them from touching the guides; and there were three fixed guides, 1½ inches in diameter, fitted on the outside of each cage. Ordinary winding-ropes and two kinds of non-spinning ropes were not found satisfactory, as they twisted the cages in the centre of the shaft, where the guides were not stiff enough to keep them in position; and finally locked-coil winding-ropes were adopted. The cages now hung square at meetings, and hardly ever touched the two loose central guides. Locked-coil winding-ropes were more expensive than those used with wooden guides, and this extra cost must be added. If the treads of the pulleys were true and locked-coil winding-ropes were used, there was very little swaying of the

cages, and they could be run close to the central rubbing gui
The initial cost of the rope guides is detailed in Table I. The

TABLE I.—COST OF ROPE GUIDES AT PLEASLEY COLLIERY.

	£	s.	d
Six rope guides, 1½ inches in diameter, at £50 each	300	0	(
Two ,, 2 ,, ,, ,, ,, ,, £85 ,, ...	170	0	(
Cast-iron weights, 30 tons at £4 10s.	135	0	(
Labour of fixing	30	0	(
Total	£635	0	(

state of the upcast-shaft makes the rope guides wear rapi
and they only last about five years; but the two rubber gu
last longer. Allowing £80 per annum for renewals
£50 per annum for the enhanced cost of the special wind
ropes over and above the cost of the ropes used in the downc
shaft, the total cost becomes £130 per annum.

Wooden Guides.—The downcast-shaft is fitted with wall-b
to receive a centre stay and two side stays at intervals of 10
There are about 300 feet of cast-iron tubbing, with brackets
on the plates. There are eight guides, measuring 4¾ inche
4¼ inches, two being fitted on each side of each cage. The
of installing the wooden guides is detailed in Table

TABLE II.—COST OF WOODEN GUIDES AT PLEASLEY COLLIERY.

	£	s.	d
159 central stays of oak, 16½ feet long, 8 inches wide and 9 inches deep, at £1 9s. each	230	11	(
318 side stays of oak, 13 feet long, 6 inches wide and 9 inches deep, at 17s. each	270	6	(
Cast-iron wall-boxes, two large ones and four small ones, say, 5 cwts. every 10 feet, 40 tons at £8 per ton ...	320	0	(
Eight pitchpine conductors, 1,580 feet long or 12,640 feet at 7·81d. per foot, the average price over 8 years	411	6	(
Wooden jointing of conductors	50	0	(
Pins for the conductors, 30 cwts. at 13s. 6d. per cwt. ...	20	5	(
Labour of fixing: this does not include the cost of fixing the wall-boxes	420	0	
Total	£1,722	8	

The annual cost of maintenance has been as follows:—The o
stays gave little trouble for twenty years, but since that pe
several of them have been replaced, and, allowing 5 per cent
annum on £500, the cost has been £25; the actual average

of pitchpine conductors over the past eight years has been £60; labour, refixing, renewing pins, etc., 60 shifts at 27s. per shift, £81; add the loss of three breakages per annum at 1½ hours each, or 4½ hours' standing at 120 tons per hour, or 540 tons at 1s. per ton, £27; and the total is £193. The shaft contains about 300 feet of cast-iron tubbing, with brackets cast on the plates to receive the wooden stays, so that it would be impossible to adopt two wooden stays with end-guides to the cages, even if it were desirable to do so.

It will be seen from the preceding figures that the first cost of the rope guides at the upcast-shaft was rather more than one-third of the cost of the wooden guides at the downcast-shaft, whilst the annual maintenance for ropes is £130 as compared with £193 for wood. The annual charge of £130 for the maintenance of the rope guides is considered very high, but it is due to the short life of the guides; and, if they had been placed in the downcast-shaft, their life could be easily doubled. Rope guides used in a dry shaft will last from twelve to fifteen years. Wooden guides are found to wear most rapidly at the place where the engineman begins to steady the cages. Oregon pine had been tried, but it had been replaced by pitchpine. It must not be overlooked that three months were occupied in fixing the wooden guides, working three shifts of eight hours for seven days a week, while the ropes, guides and cages were fitted in a week; and, at Pleasley colliery, the fitting of the upcast-shaft with wooden guides would have meant the loss of thousands of tons of coal.

THE MIDLAND COUNTIES INSTITUTION OF EN(EERS AND MIDLAND INSTITUTE OF MIN CIVIL AND MECHANICAL ENGINEERS.

JOINT GENERAL MEETING,
HELD AT CHESTERFIELD, MARCH 9TH, 1907.

MR. W. G. PHILLIPS, IN THE CHAIR.

The SECRETARY announced the election of the follc gentlemen to The Midland Counties Institution of Enginee

MEMBERS—

Mr. E. J. H. CHRISTIE, Electrical Engineer, Bank Chambers, F Sheffield.

Mr. THOMAS PERCY NICHOLSON, Mining Engineer, Hillcrest, Shepher near Dover.

Mr. JOHN SMITHURST, Manager, West Cannock Collieries, West C House, Hednesford, Staffordshire.

STUDENTS—

Mr. CHARLES OATES, Student, Kirkby Road, Sutton-in-Ashfield.

Mr. GEORGE PATRICK LITTLEWOOD, Student, Blackwell, Alfreton.

DISCUSSION OF MR. I. HODGES' PAPER ON ACCOUNT OF SINKING AND TUBBING AT MI LEY JUNCTION COLLIERY, WITH A DESCRIP OF A CAST-IRON DAM TO RESIST AN OUTBU OF WATER."*

Mr. G. ELMSLEY COKE (Nottingham) said that he knev Whitwood collieries, but had not seen that shaft since tl tubbing. The shaft was sunk on a large fault which crosse measures, and ran through the canal, causing large feed water. Mr. Hodges had the very difficult problem of m the shaft watertight and secure, and he appeared to have s it with skill and success. The tubbing might now be exp to endure for the extended life of the mine.

* *Trans. Inst. M. E.*, 1906, vol. xxxii., page 76.

Mr. H. R. Hewitt said that the work undertaken by Mr. Hodges appeared to have only just been in time to avoid the collapse of these shafts, and was a suggestion to those having old shafts in use to examine their tubbing and ascertain the thickness of the plates from time to time. In deciding upon a new centre-line, the thickness of the new tubbing-plates prohibited the centre-line from being moved far, as the author did not appear to have taken any of the old tubbing out of the shaft. It appeared strange that the work of putting a dam in the upcast shaft was not done some years earlier when the water was found to be troublesome, as the cost was so insignificant compared with the annual charges dispensed with. It was well known that formulæ for ascertaining the thickness of tubbing required gave a variable result, and when these were placed side by side in Table VI.* it would appear that the one given by Mr. W. Galloway should in future be dispensed with as being altogether misleading, and no harm could be done by erring on the side of safety in a matter of this kind. When so wide a difference as 0·05 inch to 0·50 inch was given for the thickness of tubbing at the same depth, there was a great error somewhere, and yet the author of the paper used a thickness of 0·75 inch for the same depth in these shafts. It would be interesting to know what formula he adopted for this, and why he considered such a thickness necessary at a depth of 60 feet, for which, taking this as his standard, the extra cost involved must have been very great. Although shaft-work of a dangerous nature was frequently being done, it was gratifying to notice that the number of accidents was so few, and this was a creditable record of the skill and foresight displayed by Mr. Hodges and his officials.

Mr. Isaac Hodges, replying to the questions asked by Mr. J. S. Barnes† at the last meeting, thought that he had made it clear in his paper that the upper length of tubbing, 260 feet, stood on one foundation crib only, the total weight on that crib being 286 tons. He agreed that this was a heavy weight for one crib; but it was quite impossible to make an attachment to the old tubbing, nor was it desirable, as it was in so shaky a condition as to be scarcely able to stand the pressure which it already had to bear. Mr. Barnes said that he disliked cribs being spaced at greater

* *Trans. Inst. M. E.*, 1906, vol. xxxii., page 96. † *Ibid.*, page 98.

distances apart than 60 feet. There was something to be said f cribs being spaced at frequent intervals, but, at Methley Ju tion colliery it was impossible to do otherwise than stand t whole length of the new tubbing upon the foundation-crib bel the old tubbing. Mr. Barnes had asked how the horizontal a vertical sheathings were inserted. The tubbing was built rings at the surface by means of a turntable on the drawbrid and the vertical sheathing was placed in position at the time wl the rings were being built up. A ring of tubbing was run o the pit, lifted, the drawbridge withdrawn, and the ring of t bing lowered into position. The workmen followed afterwa in a kibble, saw the ring of tubbing placed in position, a then laid the horizontal sheathing for the next ring bef returning to the surface. It was by that means that they w able to complete and put into position a ring of tubbing ev 40 minutes; and, by working 24 hours per day, the upper sect of 140 feet was completed and placed in position in less tl two days. Referring to the remarks as to coating, he thou that Dr. Angus Smith's composition was a great safegu against corrosion. The original tubbing had been pa destroyed by internal corrosion, and he thought that the use composition on the new tubbing would tend to remedy that e The casting of figures in relief on the face of each segment tubbing indicating the thickness would enable his successor test the then thickness, and so form an accurate judgment a the deterioration. It was difficult to refer to old figures plans, perhaps a quarter of a century old; and it seemed to that there was greater safety in having the figures cast on tubbing, and knowing that those figures indicated the orig thickness. Tests would then either give them a sense of secu or prompt them to take speedy measures to remedy the def Since the paper was written, the slight leakage past the plu the second pipe had diminished until it was now quite dry. would be remembered that, when the dam was completed, at 100 gallons of water passed per hour; within a fortnight quantity was reduced to 25 gallons per hour, and it further gra ally reduced to 9 gallons per hour. The shaft was now quite and no sign of water had shown itself in the workings. A sav of upwards of £1,300 per annum in pumping had been acc plished by an expenditure of £1,590 on the dam.

In calculating the strength of tubbing required to resist the pressure of water, he had occasion to take from various text-books the thickness of tubbing as worked out by Messrs. J. J. Atkinson, W. Galloway, G. C. Greenwell and W. Tate. He was much struck by their divergence, and it occurred to him that it might be of benefit to have these formulæ put side by side for comparison. He then compared the tested thicknesses of the old tubbing with the patterns from which the tubbing had been cast in their own foundry about 1850, and at once he saw that the half-century's usage had resulted in serious deterioration, in quality quite as much as in thickness. Therefore he came to the conclusion that the formula generally adopted was inefficient, and needed revision. The thicknesses of tubbing given in Table VI.* showed, so far as shallow depths were concerned, that they were much too light. In his case, tubbing 1½ inches thick had diminished in thickness to $\frac{7}{16}$ inch after a usage of about half a century, and he had therefore worked out a formula including a constant allowing for corrosion and wear-and-tear. Although the formula might perhaps be criticized as giving an unusually heavy thickness, that was a fault which mining engineers would agree was not a particularly grave offence. The dangers from weak tubbing were serious and out of all proportion to the saving made in the original capital expenditure. The formula that he had used was:—

TABLE I.—THICKNESSES OF TUBBING CALCULATED BY THE FORMULA: $T = \frac{PR}{S} + C$, TOGETHER WITH THE ACTUAL THICKNESSES USED IN THE METHLEY JUNCTION SHAFTS.

Height of Tubbing.	Thicknesses of Tubbing calculated from the above Formula.	Thicknesses of Tubbing actually used in Methley Junction Shafts.
	I.—Shaft: 10 Feet in Diameter.	
Feet.	Inches.	Inches.
60	0·69	0·75
100	0·82	0·87
140	0·95	1·00
180	1·08	1·12
220	1·21	1·25
260	1·34	1·37
	II.—Shaft: 11 Feet in Diameter.	
300	1·45	1·50
340	1·59	1·62
380	1·74	1·75
420	1·88	1·87

* *Trans. Inst. M. E.*, 1906, vol. xxxii., page 96.

$T=(PR/S)+C$: in which P is the pressure in pounds per sq inch; R, the internal radius of the tubbing in inches; T, thickness of the tubbing in inches; S, the safe stress of cast- or 8,000 pounds per square inch; and C, a constant provi for corrosion and wear-and-tear, namely:—½ inch for depths exceeding 300 feet, ⅝ inch for depths exceeding 300 feet but exceeding 600 feet, and ¾ inch for depths exceeding 600 The actual thicknesses of tubbing used in the Methley Junc shafts, as compared with the thicknesses calculated from above formula, were recorded in Table I.

The CHAIRMAN (Mr. W. G. Phillips) thought that mem might refer to Mr. Hodges' paper as an interesting accoun overcoming extraordinary difficulties in a masterly man They were indebted to Mr. Hodges for the trouble that he taken in compiling his paper and supplying drawings of mi correctness, which materially helped to the understanding o paper.

The further discussion was adjourned.

DISCUSSION OF MESSRS. W. N. ATKINSON A A. M. HENSHAW'S PAPER ON "THE COURRIÈ EXPLOSION."*

Mr. W. N. ATKINSON (H.M. Inspector of Mines) wrote Mr. A. H. Stokes referred to the advantages, from the poi view of safety from explosions, of having the districts of a so split up by ventilation that any catastrophe which occu would so far as possible be isolated. Whilst, however, the p system was an excellent one for several reasons, it had proved over and over again that it was of no avail for arre an explosion in a dusty pit, when the roads connecting different districts contained inflammable dust. Where in d pits, such as those in which large explosions invariably occu certain ventilating districts had escaped the effects of the e sion, the reason was found, not in the fact that they were s ately ventilated, but because there was a break in the trai dust or a change in the nature of the dust.

* *Trans. Inst. M. E.*, 1906, vol. xxxii., pages 439, 340 and 507.

With reference to the shot in the Lecœuvre heading, and the fact that it was not known to any official that it was a shot which had missed fire, the officials most likely to have known were killed, and as the miners fired their own shots it was quite possible that no official knew anything about it. The heading was not a new clean heading: it was an exceedingly dusty place, the dust, as stated in the paper, being chiefly due to the use of a percussive heading-machine.

With reference to the initiation of the explosion, whilst it was practically certain that it occurred in the Lecœuvre heading, there was still room for some argument as to the exact means. The suggestion made by Mr. Stokes as to the possibility of an explosion of Favier-powder while being handled was not overlooked; but to the writers (Messrs. Atkinson and Henshaw) the balance of probabilities appeared to be strongly in favour of the theory set forth in their paper. The cutting above and down to the shot-hole (fig. 20)* appeared to have no other object than to enable the explosive to be reached. The most difficult thing to account for satisfactorily was the dismemberment of the body of the fourth man, which was found about 60 feet from the face. Perhaps this man was nearer the face at the moment of the explosion, and in the line of the shot, and was blown and dismembered by the shot blowing out. The damage to the air-pipes did not appear so difficult to account for. Such pipes were sometimes made of inferior metal, and, if rusted and worn, required no great force to shatter them.

The shot in No. 1 experiment, at Frameries, was not fired under conditions similar to those that attended the shot in the Lecœuvre heading. In the former case, there was neither gas nor dust in the experimental gallery, whilst in the Lecœuvre heading there was an abundance of dust.

Mr. G. A. Lewis (Derby) said that he wished chiefly to draw the attention of the members to certain remarks made by Mr. A. H. Stokes,† which it was possible, unless they had carefully read the *Transactions*, might have escaped their notice. The great point about this explosion was its origin, and he thought that it was a matter of extreme surprise to many mining engineers in this

* *Trans. Inst. M. E.*, 1906, vol. xxxii., page 471.

† *Ibid.*, page 340.

country that engineers who had inspected the collieries agre that the explosion was started in a heading. It was a coal-du explosion, and it was practically unanimously decided that the was no gas whatever in the pit. The question then was, h could a coal-dust explosion be started in a heading, which cou hardly contain dust of such a quality as would, judging by th experience in this country, be liable to start such an explosio If the blown-out shot, which was supposed to have started t explosion, did really fire the coal-dust, the flame would ha had to travel 45 feet before it reached any dust. That was position which most of the members failed to comprehen Another point which seemed to have escaped the notice of ma of the members was that, whilst four men were killed in th heading, the three men who were at the far end of the headi were practically not injured at all, except by burns; but t man who was most seriously injured (in fact he had a leg and arm blown off) was 30 or 40 feet, or even more, down the headin He thought that the construction which Mr. Stokes placed up that, and the explanation that he suggested, were extreme reasonable, and such as he (Mr. Lewis) would be inclined to acce without reservation. Mr. Stokes suggested that a shot was p in at the end of the heading, that it mis-fired—not that it w blown out—and that the material for the shot had been recover out of the hole. There were indications confirming the beli that the hole had been dug out, and the explosive extracted, a it was suggested that it had been taken by one of the men so distance down the heading. Possibly he had placed it on one the air-pipes and was trying to extract the detonator from t explosive, or some mishap occurred by which he caused a deto tion, and it exploded the material that he had brought with hi The dust at this point would be more liable to explode, and t theory would explain various otherwise puzzling phenomen These conclusions, to his (Mr. Lewis') mind, accounted for t fact that the greater force of the explosion was to be seen 45 f down the heading, and that the men at the end of the headi were not affected so much. Another point which gave plau bility to this hypothesis was the fact that the air-pipes close to end of the heading were hardly damaged, while the third fourth lengths of air-pipe from the face of the heading w smashed to atoms. He thought that theory was extrem

plausible, and it would go a long way to satisfy their doubts as to why an explosion should take place in a heading, whilst at the same time affording some idea as to the precautions which should be taken in driving such a heading. The main point seemed to be whether such explosions could not be stopped entirely. It rather occurred to him (Mr. Lewis) whether those of the members who were trying to solve the problem of preventing the spread of an explosion were not proceeding somewhat in a wrong direction, and whether they should not direct their attention to the question whether these explosions could not be prevented altogether. By that he meant, was it not possible to limit the shot-firing apart from the coal-face to the period when the men were out of the mine? It was a point to which he was trying to devote his attention, and he was convinced that it was better to do that than merely to endeavour to limit the spread of an explosion, and to restrict the area which it affected when it did occur.

Mr. H. Stevenson (Linby) remarked that the dust in the heading, boot-top deep, consisted of fine coal made by a Sullivan percussive holing-machine. There was nothing in the mines of this country to compare with the dust in the Courrières mines. When down the latter he noticed that the seams were contorted and twisted, and that the coal was peculiarly soft. It could be knocked off or even scratched down by the hand, and was very like black-lead. The amount of dust made was in excess of anything found in this country.

Mr. J. T. Todd (Blackwell) said that there were one or two matters, which he found a difficulty in following. He did not think that there were any details which would tell the members, whether, if this fire occurred in the return-airway, how or why it occurred; or whether it was impossible to have occurred in any other part; nor had they anything to tell them what was the character of the coal-dust at Courrières, or an analysis of it; or whether that coal-dust was totally different from any that they found in the mines of this country. He regarded it as an exceedingly open question whether this explosion ever occurred in a heading, or whether it did not originate from gas from some other part. Of course, given an explosion, if there were fine coal-dust and plenty of it, that explosion would be extended. He certainly

did not think that they were in a position to judge definite whether the explosion at the Courrières collieries occurred in heading and from a shot. They had to assume an exceptional big charge of explosive, and that several things were do which were illegitimate and in flagrant violation of regulation before they could arrive at the conclusion that the explosion d occur in that particular place. The information was not calc lated to carry them to that conclusion. Before they cou accept the strong statement that a similar disaster might occ in this country, they wanted to know something of the charact of the coal-dust, the principle of ventilation, an analysis of t coal-dust, the temperature of the mines and the nature of t explosive which they were using. So far as he was aware, it w a fact, since the Explosives Order had been brought into oper tion, that no explosion had occurred on a main haulage-ro through the firing of a shot with any explosive which was now the Permitted List of Explosives. He agreed with Mr. Lew that, if they could find a safe explosive, and prevent flames fro blown-out shots such as they used to have from gunpowder, th would, under conditions of watering and proper supervision, ha gone far towards removing the dangers of explosions in ma haulage-roads. If they looked at the explosions which h occurred in this country and had been attributed to coal-du they would see that none of them had gone into the face—t stopped at a certain point. That indicated that the great dan was on the main haulage-roads in which were accumulations very fine dust; and, if they removed in any way that source danger, they removed very largely all danger of a repetition this country of such a disaster as that which had occurred at Courrières collieries.

Mr. A. H. Stokes (H.M. Inspector of Mines) said that Lewis had given a good *résumé* of what he had tried to empha at the last meeting. The best advice that he (Mr. Stokes) co give to Mr. Todd was to read the official reports of colliery ex sions, and they might give him an answer to many of the qu tions which he had put. He confessed that many years ago was rather sceptical about coal-dust explosions without fire-da but after the instances at Timsbury, Camerton, and the o which came especially home to him, at Blackwell, he could h

no doubt on the subject. With regard to the stoppings being blown-out, and the fire in the Courrières collieries, it was recorded that the stoppings were blown inwards: whereas, if the explosion had occurred at the fire, they would expect to have found them blown outwards. As regarded the explosion starting in the heading, about which Mr. Todd appeared to have some doubt, could Mr. Todd tell them what was the cause of the fourth air-pipe being shattered and torn into so great a number of pieces? No one could tell why the man near that air-pipe was so mutilated, an arm and a leg being found 10 feet from the body and outbye, if the explosion did not take place at the fourth air-pipe. With regard to the blown-out shot, of which so much had been made, it had been recorded by the authors of the paper that "similar holes have been observed before in these headings," and that "a somewhat similar hole has been since found at the face of the parallel heading."* The point for consideration was not so much the result of the explosion, but the best means of preventing the recurrence of such explosions. They heard a great deal about watering: it was good in its way, but if they watered a road-way for 300 or 400 feet, and it stopped the spread of an explosion, did it stop the foul gases which had been generated by the explosion from coming out and killing the men? Such gases would travel to the upcast shaft irrespective of the watered portion of the road-way—the explosion might not go all over the pit, but the foul gases would be uncontrolled in their travel when doors and stoppings were destroyed; and it was the irrespirable atmosphere after an explosion that claimed the greatest loss of life. Then came the question: If watering was only one step to the complete cure, where were they to look for safety? Let them try to put their finger upon it. He thought that Mr. Lewis went half-way towards it. Let them stop shot-firing on the road-ways during the working shift, and see whether every shot, except at the coal-faces, could not be fired at night-time or when the coal-turning shift of men were out of the pit. He did not think that they could completely get rid of shot-firing at the coal-face; but a working-face was quite different from the road-ways. In a road-way, they had an ever-increasing accumulation, day by day, of the finest dust; whereas at the coal-face there was a continuous advance and exposure of clean-cut coal. The face did not stand and allow dust to accumulate, but moved forward; and the face

* *Trans. Inst. M. E.*, 1906, vol. xxxii., page 474.

of to-day was not the face of to-morrow. There were no accumulations of dust at the face, like those in the road-ways. With regard to the limitation of an explosion, when it did start, had not the Courrières disaster taught them the lesson that if they had six pits it would be advisable not to connect them together? Had it not taught them that in laying out their mines they should, as much as was practically possible, have isolated districts from the main intake-airway to the upcast shaft? They all probably could call to mind explosions where many lives had been lost in one district, whereas men in another district had continued working without knowledge of an explosion having occurred in the mine. At the Wingate Grange explosion in October, 1906, "some of the miners [in another part] had to be warned to leave the in work, and one was so little concerned that he fired a shot about 1 a.m., or more than an hour after the explosion."* They would do well to consider what lessons they could take from the Courrières disaster.

Mr. Isaac Hodges did not think that they ran anything like the same danger in existing mines in this country as in the French, Belgian or German coal-fields. There was a great deal of difference in the fineness and explosive character of the coal-dust at the working-faces in those districts, as compared with the granular dust found at working-faces in Great Britain. He had visited one of the Belgian mines on the French border, not far distant from Courrières, and in their deepest seam he was astonished at the amount of dust found at the working-faces and on the road-ways, but especially at the working-face. The strata were contorted, the coal was very friable, and at a depth of 3,000 feet only about 5 per cent. of coal passed over a round hole, 1 inch in diameter. The amount of dust was obvious by looking at the faces of the miners themselves; they were very much blacker than the miners of Yorkshire, and in the deepest seams in that county nothing could be found to rival it. It reminded him of nothing so much as the appearance of men recovered after an explosion. The point to which he particularly addressed himself was that raised by Mr. Stokes, as to the in-

* *Reports to H. M. Secretary of State for the Home Department on Circumstances attending an Explosion which occurred at Wingate Grange Colliery, Wingate, on the 14th October, 1906*, by Mr. A. H. Ruegg, and Messrs. R. D. Bell and J. B. Atkinson, 1907 [Cd. 3379], page 23.

derground. The economies of that arrangement had been very
siderable; and, although he would not say that anything could
tify loss of life, economy certainly justified any small extra risk
t there might be in connecting such mines. He agreed that
ricts should be isolated in some manner; but he did not agree
h Mr. Stokes that districts should be isolated by leaving
riers of coal, or by being worked from disconnected pits. He
would rather that more attention should be given to the best
ns of zoning a mine, so that if an explosion occurred in one
rict it could be prevented from travelling into another. They
had some object-lessons from coal-dust explosions; and in his
case he had considered it advisable to separate districts from
other by non-dusty lengths of brickwork. This consisted
rally of brick-walls with a concrete roof, as he found it
r and cheaper, and less obstructive to the ordinary work of
mine during erection, than building semicircular arches. He
felt that the Courrières disaster was sufficiently serious to
e them attempt to do something, and by periodically
ing those zones he hoped to do a little towards preventing
explosion from spreading. He did not know whether it
ld be necessary to water those zones, but they would learn
s on that point during the course of the next twelve months.
to shot-firing, he did not know how Mr. Stokes would be
to fire all the ripping and coal-face shots required in a
e mine, with the number of men allowed by the Coal-mines

workmen were out of the mines. He very much doubted whether that could be extended to the gateways, and certainly it could not be extended to the working-faces. Shot-firing he was sorry to say, had largely increased, and nothing of late years had quite so much altered their methods of mining. In one district where 1,000 tons per day had been got without firing a shot, a considerable number of shots were now fired. Last year, upwards of 60,000 shots were fired at the Whitwood collieries, and the suggested prohibition of shot-firing would be a very serious matter to them; although he ought, perhaps, to add that he did not think that six shots had been fired on main roads, and those were the only shots which, in his opinion, required special attention or protective legislation.

Mr. A. H. STOKES said that if Mr. Hodges wanted a dusty mine, he could tell him where to get one. He (Mr. Stokes) had been down a mine, and brought away with him some of the dust, which he had not been able to get rid of for days. He was surprised that Mr. Hodges thought that ten men were insufficient for shot-firing on road-ways, for he concluded his remarks by saying that he had not fired six shots on main roads in a year.

Mr. I. HODGES stated that ripping shots were not included in the main-road shots.

Mr. A. H. STOKES said that he had got the statistics of the number of shots fired in his mines-inspection district during the last year, and he was very pleased to congratulate the members upon the considerable decrease (88,341) in the number of shots fired. He had intended to suggest that, instead of carrying the main intake-air in one current and splitting it up into districts near the face as possible, the intake and return-airways for each district should be made as distinct as possible, so that if an explosion occurred it should, if possible, be confined to one district. There were many difficulties, but there were other ways of doing connecting districts in old collieries. In his mines-inspection district, one mining engineer had thought so much of the Courrières disaster that he had put in iron doors to separate two seams. He (Mr. Stokes) had seen them, and he felt satisfied that the doors and the way in which they were built in would stop an explosion extending from one seam into the other, so far as the

doors were concerned. Supposing it were made obligatory not to fire any shots whatever in main road-ways, except under the conditions suggested, then the rule or regulation containing the prohibition might also include permission for more men to be allowed in the mine if, as Mr. Hodges contended, ten was an insufficient number. The legislative enactment that made prohibitions could also make extensions, if necessary.

Mr. I. HODGES said that, if they could separate seams with two iron doors, it would be much cheaper than the method which he was adopting. He asked whether they entirely cut off the intake and the return-airways, and closed the passages into the mine.

Mr. A. H. STOKES said that the doors were used to separate one seam from another, and they were put in between the shafts. The best plan would be for Mr. Hodges to see them, and he would gladly tell him where they were.

Mr. M. DEACON (Sheepbridge) said that he did not altogether see any special advantage in discussing the Courrières explosion. Unfortunately, a number of explosions, equally instructive, had happened in this country, and it was only the large number of men who lost their lives in the Courrières explosion that attracted so much attention to it. An explosion in this country in which one man was killed might be of as great importance to them, as mining engineers, as this disaster in France, in which 1,100 lives were lost. All it had done for them was to give rise to a renewal of the consideration as to how they, in this country, could reduce the risks of similar explosions. He thought, as Mr. Stokes had said, that there was ample evidence of a coal-dust explosion in the results at Camerton. With regard to the Courrières explosion, he should be extremely sorry to give any opinion, or to come to any sort of conclusion, without having seen the mine very soon after the explosion. The question of preventing the spread of an explosion was a large one. No doubt the arrangement of ventilation-areas in such a way as to limit any explosion which might occur was a proper thing for the members to take into consideration; but it was a matter for each colliery manager to consider for himself. No general rule could be laid down. The dividing of collieries by barriers was absolutely prohibitory, because with the deep sinkings which they had in front of them no colliery

owner would be disposed to sink to much less than 20 squa
miles where only one seam existed. Those were big figures, b
he was now drawing coal 2¾ miles from the shaft and doing
economically. He was sure that colliery owners were not goi
to sink £500,000 in a colliery without working a very lar
area, only limited by the distance over which they could economi
ally draw the coal to one shaft. Therefore, the suggestion
separate a mine into small compartments for the purpose
limiting the effect of an explosion was not within the sphere
practical mining. He had made many experiments in waterin
over the past twenty years: he had tried watering by jets,
barrels after the manner of street-watering, and also by layi
water-pipes, with taps at distances of 100 or 150 feet, waterin
the floor, sides and roof of the roads, by means of a hose and ro
He was very strongly impressed with the desirability of waterin
wherever the roads would stand it; and where they would, a
especially where the dust was of a fine and impalpable characte
they ought certainly to be watered. In the Tredegar explosio
they had direct evidence of the fact that watering the roads h
hindered the progress of the explosion. The explosion occurr
at the face; the main intake-airway had been perfectly a
thoroughly watered, but the return-airways had not been wate
and were very dusty. The explosion took place at the workin
face, but instead of going out by the intake-airway it follow
the return-airway to the pit-bottom. The onsetters were bu
and the men in the intake-airways were not touched. He had
hesitation in saying that watering did a great deal towards lim
ing the seriousness of the Tredegar explosion.

Mr. J. T. Todd said that Mr. Stokes had recommended h
very strongly to read the official reports. Would Mr. Sto
kindly tell him in what report he would find any record, si
the Explosives Order was instituted, where an explosion h
occurred by shot-firing on a main haulage-road with any of t
present Permitted Explosives?

Mr. Stokes replied that, if Mr. Todd's remark had referen
solely to a main haulage-road, he had misunderstood him. I
believed, however, that there was such a case, and he wou
give Mr. Todd some quotations in confirmation. In the report
the Wingate Grange explosion, the verdict of the jury was to t

effect that the deceased had been killed "by an explosion caused by the firing of a shot in the main haulage-way in the Low Main seam."* H.M. inspectors of mines report that "the point of origin and the initial cause of the explosion was a charge of the Permitted Explosive geloxite fired by a stoneman by means of fuse on the main haulage-road," and "the inflammable agent, both at the origin and in the propagation of the explosion was coal-dust and not fire-damp."† Geloxite was a Permitted Explosive on the present list, and it was only five months since the Wingate Grange explosion had occurred.

The CHAIRMAN (Mr. W. G. Phillips) said he felt that the discussion was not by any means exhausted, and that the paper was a most valuable contribution towards their knowledge of extensive explosions. Whatever might have been the cause of the explosion, whether it was initiated by coal-dust alone or found some assistance from an accumulation of fire-damp at the seat of the accident, there could be no doubt that it owed much of its vitality and devastating power to the dusty condition of the roads. He had come to that conclusion by diligently reading this paper by Messrs. Atkinson and Henshaw. Confining himself to the Lecœuvre heading he found, on making a slight calculation, that no less than 19 inches of explosive had been used in the particular hole which it was assumed the men were undrilling at the time of the accident. Mr. Lewis made a remark to the effect that the three men at the end of the heading were not much injured, but there were plentiful indications in the heading, in the shape of coked and charred coal-dust, of flame, and the bodies of the men were reported by the doctor to be deeply burned. Certainly, they had no indication whatever as to the state of the ventilation in this particular part of the workings previous to the explosion, but there was a pair of levels heading from the top of a jig, rising 1 in 6. They had been driven about 500 feet, and to his mind it was very ominous indeed that on the date when this explosion happened there was no one working in the counter-heading. They did not know why, but the workings

* *Reports to H.M. Secretary of State for the Home Department on the Circumstances attending an Explosion which occurred at Wingate Grange Colliery, Wingate, on the 14th October, 1906*, by Mr. A. H. Ruegg, and Messrs. R. D. Bain and J. B. Atkinson, 1907 [Cd. 3379], page 13.

† *Ibid.*, page 32.

ELLIOTT WASHER AND HARDY DUST-EXTRACTOR AND GRINDER.

By E. GREAVES.

Introduction.

The growing spirit of economy in the coal-mining indust and the pressure that is being brought to bear on colli managers by the Government authorities to avoid, wherever p sible, the gobbing of coal on account of the danger of gob-fi without mentioning the national economic side of the questi are doubtless to a great extent the reasons why large quantit of small coal, which were formerly gobbed, are now drawn to surface. The appliances introduced during the last few years utilize small and inferior coal for generating steam, maki briquettes, etc., the ever increasing demand for coke, etc., m slack and duff, which were formerly looked upon almost as wa a very valuable product. At present there is hardly any class small coal which cannot be utilized either for coking or briquetting, for hand or mechanical firing, if the percentage ash in it is not too high.

Coal-consumers now seek economy far more than former and refuse to buy coal containing much free ash; coal-own are far keener than they were to utilize every possible produ and bye-product plants are being erected in all directions, so t coal-washers, which at one time were a rarity, are now becomi general, and in a few years will become as necessary a part o colliery-plant as the screens and sidings. Where there w formerly two or three sizes of coal, there are now a dozen, a washed peas, washed breeze, washed nuts, smudge, etc., everyday terms in the coal-trade.

Elliott Washer.

The Elliott coal-washer is based on the theory of all c washers, namely, that the coal and shale dirt, being of diffe specific gravities, fall through water at different velocities; shale being heavier than the coal, if approximately of the s

cubic capacity, offers more resistance to the stream of water and settles, whilst the coal being lighter is carried away with the stream. The Elliott is an improvement on the old trough-washer, at one time so much in favour with colliery managers on account of its simplicity and efficacy. Indeed, it only fell into disuse because too much depended on the attendant in charge, as it was necessary to run the coal and water into the second trough so soon as the dams or stops in the first trough had got charged with dirt; and, unless this was done at the right moment, the dirt in the dams or stops was carried away with the coal, with consequent bad washing results. The labour required in removing the dirt from the dams was a serious item, besides the cost of the second trough and the extra space necessary. Furthermore, the old trough system was hardly elastic enough for modern requirements.

The Elliott trough-washer possesses all the advantages of the old system without any of the disadvantages, being absolutely automatic in its action, requiring no skilled attendant or manual labour; and each trough washes continually without interruption, the coal and water being delivered at the lower, and the dirt at the upper end. The Elliott trough (fig. 1), which is generally fixed at an inclination of 1 in 12, is constructed of cast-iron or steel with a flat bottom 18 inches wide, and sloping sides, giving a width at the top of 30 inches; the total length is 60 feet and the depth usually 11 inches. At each end of the trough, sprocket-wheels are fixed, which carry an endless chain. At right angles to this chain, scrapers are attached at suitable distances, which are of the same section as the lower part of the trough. The scraper-chain travels along the bottom of the trough to the upper end, and runs back over the trough on bracket-rollers, bridged at intervals over the trough, the chain being driven by the sprocket-wheels at the upper end. The scrapers in this manner form travelling dams, which catch the shale and dirt settling in the bottom of the trough, and carry them to the upper end; whilst the lighter coal is carried by the water over the dams and delivered at the lower end.

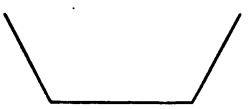

FIG. 1.—TROUGH.

The coal from which the fine dust has been removed is delivered into the trough at a point about 25 to 30 feet from the top end. The water, being admitted as near the upper end as

possible, runs down the trough and cascades over the scrapers, taking with it any coal that may still be mixed with the dirt. When it arrives at the delivery-points of the coal, about half-way down, its chief determinating action begins; the heavier shale and dirt settle down, and, being caught by the scrapers, are conveyed to the upper end, whilst the lighter coal is washed over the scrapers by the stream to the lower end, where it is discharged on to oscillating or other water-screens. These practically free the coal from the water, which runs into a cistern and then pumped back to the upper end of the trough to be used again. It will thus be seen that the upper half of the trough's length serves to wash the dirt and shale free of coal, whilst the lower half serves to wash the coal free of shale. When the washer is at work it will be noticed that the scrapers, as they begin to ascend the trough at the bottom end, are dammed up with coal as well as shale, the whole, however, turning over and over from the action of the water running in the opposite direction down the trough. As the scrapers proceed to the upper end it will be noticed that the coal behind the dams is gradually churned up and carried away by the water, so that when they arrive at the upper end, the scraper-dams are free from coal, and discharge nothing but shale and dirt.

Formerly, the Elliott washer was fitted with flat straight scrapers driven by one chain, which gave perfect results with nuts, etc., and fairly good results with duff. Practical experience, however, shewed that better results might be obtained by altering the structure and shape of the scrapers. Duff requiring a slower action of the water, it was found that the natural tendency of the water to follow the line of least resistance caused the coal in the middle part of the trough to be perfectly freed from shale, whilst the coal at each side of the scrapers was washed less effectively. To obviate this defect, new types of scrapers, driven either by a single or by a double chain have been introduced. These scrapers are made either convex or concave, or serrated throughout their width, in such a way that the water, on reaching each scraper, is baffled into several channels instead of running in one as formerly. This ensures continuous movement to the material as it is transported by the scrapers from one end of the trough to the other, and the washing is equally effective throughout the whole width of the scrapers. By this arrangement the improved Elliott washer can treat perfectly any size of coal

down to the finest dust, so that even the finest grains are washed, and the dust being so slight a percentage of the whole, it can be added to the washed coal without materially increasing the percentage of ash; modern requirements are thus met, the whole of the duff utilized, and any loss avoided.

The troughs are supplied with a differential headstock, so that the speed of the scraper-chain can be varied to suit the class of coal that is being washed. It is advisable to have a water-cistern at the upper end, fitted with spray-taps, so that the operator can regulate the volume of water for each size of coal.

To ensure perfect washing, that is, shale free from loose coal and coal free from loose ash, the coal before washing should not only have the fine dust carefully eliminated, but it should be classified. The Elliott being a stream-washer does not require the same amount of classification as in piston and other washing systems. Theoretically, the coal being washed should never exceed in cubic capacity three-and-a-half times the size of the smallest piece of shale, assuming the average specific gravity of coal to be 1·4 and that of carboniferous shale 2·4. If the specific gravity of the material that is being treated differs from the above, the results will be different; but the practical results of washing with the Elliott trough, in many countries, and with practically every class of coal and shale, have shown conclusively that only three sizes are necessary for washing, that is: (*a*) ⅛ inch to ¼ inch, (*b*) ¼ inch to ¾ inch, and (*c*) ¾ inch and upwards.

Mr. Franz Poech,* in a lecture given in Vienna a few years ago, explained the action of the Elliott washer as a continued forcing forwards of the particles against the counteracting friction and inertia of the same, the former being of less importance than the latter. The particles of coal being treated are exposed to the pressure of the water, and carried forward by impact and pressure, so that if p is the pressure of the water; d, the ideal diameter of the particles†; and s, the distance along which they are exposed to the pressure of the water; the motive force may be written: F equals pd^2s, and the moment of inertia, M equals P/g, may be expressed thus:—

$$\frac{Mv^2}{2} = \frac{Pv^2}{2g} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

* "Ueber einige Bergwerksapparate," by Mr. Franz Poech, *Oesterreichischen Zeitschrift für Berg- und Hüttenwesen, Vereins-Mittheilungen*, 1895, page 35.

† The ideal diameter is the diameter of a sphere of a mass equal to that of the irregular particle.

In the preceding formula, M is the mass; v, the velocity in f per second; P, the weight of a particle in water; g, the accele tion due to gravity; and as P equals $\pi d^3(\delta-1)/6$ where δ is specific gravity of the coal, then the formula (1) becom $\frac{Mv^2}{2}$ equals $\frac{\pi d^3(\delta-1)v^2}{12g}$. Neglecting friction: pd^2s equals equals $\frac{\pi d^3(\delta-1)v^2}{12g}$; v^2 equals $\frac{12pd^2sg}{\pi d^3(\delta-1)}$, and v equals $\sqrt{\frac{12ps}{\pi d(\delta-}}$ Consequently, if $\frac{12psg}{\pi}$ equals the constant C, then:

$$v = \sqrt{\frac{C}{d(\delta-1)}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad .$$

Similarly for a particle of the diameter, d_1, the spec gravity, δ_1, and at a velocity, v_1, it follows that:

$$v_1 = \sqrt{\frac{C}{d_1(\delta_1-1)}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad .$$

The second (2) equation being divided by the third (3) eq tion, and each side being squared, it follows that:

$$\frac{v^2}{v_1^2} = \frac{d_1(\delta_1-1)}{d(\delta-1)} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad .$$

When v equals v_1, the point at which the separation particles of different diameter and different specific grav is no longer possible, the equation (4) becomes:

$$1 = \frac{d_1(\delta_1-1)}{d(\delta-1)}, \text{ or } \frac{d}{d_1} = \frac{\delta_1-1}{\delta-1} \quad . \quad . \quad . \quad . \quad .$$

It follows, therefore, that separation is no longer possible wl the diameters of the particles are inversely proportional to th specific gravity minus 1.

This bears out the formula that von Rittinger deduced fr the laws of gravitation: v equals $2{\cdot}44\sqrt{D(\delta-1)}$, in which 2 is a constant arrived at from practical experiments.* Thu δ equals 1·4, the specific gravity of coal; and δ_1 equals the specific gravity of shale; the equation (5) would sh that $\frac{d}{d_1} = \frac{\delta_1-1}{\delta-1} = \frac{2{\cdot}4-1}{1{\cdot}4-1} = \frac{1{\cdot}4}{0{\cdot}4} = 3{\cdot}5$. Consequently, d equ $3{\cdot}5d_1$, demonstrating that the diameter of the grains particles of coal should correspond with the grains or parti of shale as 3½ to 1. Of course, where a fixed constant is c assumed, one naturally doubts a result obtained from suc basis, but the writer repeats that many years' experience of

* *Lehrbuch der Aufbereitungskunde*, by Prof. von Rittinger, 1867, page 1

Elliott washer in different countries, with all sorts of coal and shale, has shewn that to get the best results in washing, the coal should be classified in such a way that the smallest grain of shale should not be exceeded more than $3\frac{1}{2}$ to 4 times by the largest piece of coal in that particular category. One to four has been adopted for practical purposes, so that when up to $\frac{1}{8}$ inch is eliminated, for coking or briquetting purposes three sizes only are necessary, that is: (*a*) $\frac{1}{8}$ inch to $\frac{1}{4}$ inch, (*b*) $\frac{1}{4}$ inch to $\frac{3}{4}$ inch, and (*c*) $\frac{3}{4}$ inch and upwards.

For sale purposes, such as washed smudge, peas, small and large breeze, nuts, etc., it is best to classify before washing, and treat each size in its trough or troughs according to quantity, not losing sight of the economical question as regards the number of troughs.

The output per trough depends on the size and nature of the coal that is being treated, but generally varies from 4 tons per hour for the smallest size ($\frac{1}{8}$ inch to $\frac{1}{4}$ inch) up to 12 tons per hour for large nuts. If the number of troughs be limited, and classification after washing be compulsory, the screening should be confined as far as possible to the larger sizes.

Hardy Dust-extractor.

The removal of very fine dust is always a matter of some difficulty, especially if the coal be damp or sticky, unless hydraulic screens are used; and sometimes it has been found to be impossible to screen out anything less than $\frac{1}{4}$ inch. Where only small breeze was washed, say, up to $\frac{1}{2}$ inch or $\frac{3}{4}$ inch, it was found impracticable to eliminate $\frac{1}{4}$ inch as it formed too great a proportion of the coal that was being treated; and when attempts were made to remove $\frac{1}{8}$ inch the holes in the screen-plates became clogged, and the screening results were very bad. Experiments were made in order to overcome this difficulty, which resulted in the introduction of the Hardy dust-extractor, a very simple contrivance. With this dust-extractor, it is possible to extract down to $\frac{1}{16}$ inch if the coal is dry, so that all the coal from $\frac{1}{16}$ inch upwards can be washed. Any sized grain of coal can be treated successfully with the Elliott washer; the only unwashable stuff is the very fine dust, and, in consequence of the possibility of washing down to $\frac{1}{16}$ inch, all the dust may be added to the washed coal without increasing seriously the percentage of ash in the whole.

As the whole of the dust and schlamm are used, there practically no loss with the improved Elliott washer, the outp of coke per 100 tons of coal treated being higher than with a other system.

The Hardy dust-extractor is fitted over the screen which si the coal that enters the washing troughs. The small stuff, up t inch falls into a hopper or receptacle, fitted with two or thr angular plates or baffles, so arranged as to spread the falli material into a thin stream. In its descent it comes into cont with a current of air from a fan, or induced draught, sufficien strong to carry away the fine dust-particles and draw the through an opening into a special chamber; whilst the larg stuff falls down a shoot on to a conveyor, which delivers it in the washing troughs. The dust-outlet is fitted with a baffli screen to prevent any stray grains from escaping with the du which is carried into a special hopper where it is delivered on to conveyor and transported to the disintegrator to be well mix with the washed coal whilst being ground. The dust-hopper chamber is fitted with an opening at the top, to allow of the a escaping when the coal-dust has settled. If the dust, which removed, contains a high percentage of ash, the whole of cannot, of course, be added, as this would increase too greatly t percentage of ash in the washed coal. For example, if the coa dust under $\frac{1}{16}$ inch be estimated to represent 10 per cent. of t whole of the coal to be treated, assuming that the dust fro 0 to $\frac{1}{16}$ inch contain the same proportion of ash as the larg coal, and assuming that the ash in the coal be reduced from per cent. to 5 per cent. by washing, the addition of the whole the dust would increase the percentage of ash in the washed co to 6¼ per cent., or if only half the eliminated dust were added, about 5½ per cent.

This mixture of the whole, or certain proportions, of the du with the washed coal renders the Elliott washer as elastic as t more complicated and costly systems, because the percentage ash in the coal, coke or briquette can be regulated according the exigencies of the contract or the market. In the precedi example the minimum is 5½ per cent. and the maximum 6¼ p cent. of ash, schlamm being left out of the question, as it amou generally to only 2 tons per 100 tons treated, if the dust well screened out; but, if a higher maximum limit is requir

this can be easily obtained by eliminating up to ¼ or ⅜ inch by regulating the dust-extractor accordingly. In the case of coal not destined for briquetting or coking, the desired proportion of dust should be mixed only with the smallest size of washed coal, as added dust spoils the appearance of beans and nuts; in fact, where washed coal is not coked or briquetted, it is better to have an extra category of small to receive the dust and to be disposed of as washed smudge.

Working of the Elliott Washer.

If the dust be well eliminated, a settling pond or tank is not absolutely necessary in washers for coking or briquetting purpurposes, as the proportion of schlamm is very small (about 2 per cent.) so that the density of the water is not seriously affected, and the washing results remain practically the same with or without decanting tanks. But, in the case of washed coal for sale, tanks are advisable, as a finer washed sample is produced if the schlamm is allowed to settle in a decanting tank. Even if the nuts are sprayed with the fresh water, the final result with this class of washer (non-coking) is not so satisfactory as with some systems of decanting the water before it is used again. The different mode of action in the piston-type of washer entails far more classification to get the best washing results, which explains many of the complications in this class of washer, leading to increased friction and consequent increase of the schlamm, the bugbear of coal-washing.

It is satisfactory to know that the schlamm in the Elliott washer is reduced to an absolute minimum, as the coal only undergoes one operation, whilst in the more complicated piston-washers it is transported to and fro, which results in increased friction, causing a larger proportion of schlamm. In some Elliott washers settling tanks are dispensed with, the water from the troughs being collected in a receptacle tapered down to the inlet-pipe of the pump, the schlamm circulating with the water until it settles either with the coal or with the dirt. This process of settlement is so regular that the fresh delivery-water suffices to keep the water sufficiently clear to get good washing results. There are Elliott washers with settling tanks giving only 4 tons of schlamm per week on a total output of 1,600 tons, or ¼ per cent.; in other washers the quantity of schlamm will reach 2 per

cent., much depending on the nature of the coal, the effectiv removal of the dust, and good practical water-screens.

Where the difference between the specific gravity of the co and that of the dirt is small, the question of the inclination the trough is important; but an inclination of 1 in 12 is suitab for general purposes, and is usually adopted. Generally, co upwards of 2 inches in diameter is not washed, hand-pickin being more practicable; but if coal between 2 and 3 inches is be washed, an inclination of 1 in 10 will be found to yield bett results.

For the larger sizes of coal, such as nuts, etc., scrapers 4 to feet apart and $2\frac{3}{4}$ inches in depth will give perfect results; b for the smaller sizes, such as beans, smudge, etc., the scrape should be fixed only 2 feet to 3 feet apart and $1\frac{1}{2}$ inches to 2 inch in depth. By adapting the speed of the chain, the number ar height of the scrapers, the inclination of the trough, and th volume of water to the class of coal that is being washed, abs lutely perfect washing results may be obtained with any coa which differ in specific gravity from the shale that is to be washe out: this is done at one operation, proving this to be th simplest, most effective, and most adaptable coal-washing syste This adaptability and elasticity are of vital importance, as, f instance, where the coal being treated contains any batten co or coal with streaks of shale, the water can be so regulated to deliver it either with the shale or with the coal, as required

The Elliott washer possesses an advantage over the pist washer that is not generally known, namely, its effective tre ment of shale-flats, and the thin lenticular shale so prevalent some coal-seams. These float away with the coal in the pist washer, whilst the peculiar dam-action of the trough-was ensures the flat thin shale being caught long before it reac the lower end of the trough; and, when once shale gets caught a scraper, it rarely escapes before it is expelled at the upper e The writer does not maintain that it is impossible for a t piece of shale to escape with the coal, but he contends that proportion is very trifling compared with the piston-type washer. The writer has seen washed nuts from a large mod piston-washer plant being treated by special screens, so c structed that the cubical nuts ran over the screens, whilst flat lenticular pieces of shale fell through the narrow specia arranged meshes. There were such large quantities of t

lenticular shale, that the nuts were practically unsaleable until it was removed.

It is evident that the motive power required for washing with the Elliott trough is considerably less than for washing in a piston-washer, and that the maintenance-charges are a mere trifle in comparison. The wear-and-tear is practically confined to the scrapers, which, being of very simple construction, can be easily made by any ordinary colliery-smith in his spare time. If the water which is used is moderately free from acid, the trough-sheets will last for years.

After it is once regulated for the coal that is being treated, the Elliott washer requires no attention, so that the man in charge can devote the bulk of his time to some other work. When the washer is stopped, all the water at once runs down to the pump-well so that no airtight buildings are required, as nothing can freeze even in the severest winter; and, as there is no quick running or heavy machinery, only a light structure is required. In plants for coking or briquetting, the grinding machinery is always placed on the ground floor. Each ton of coal that is being washed requires about 700 gallons of water in circulation; and, if the dust is well eliminated and the proportion of breeze and nuts is about equal, the water-wastage will be very low, well under 5 per cent., 35 gallons per ton washed: for the Elliott water-screens are very effective, and the wastage is confined to the water in the washed coal. It will be found that very little fresh water is necessary to keep up the washing supply if special arrangements are made to free the washed coal thoroughly from water by running it on a perforated conveyor as it is delivered from the water-screens, the conveyor being provided with catch-drops at suitable distances to shake and turn over the coal.

It is impossible to determine the motive power that will be required, as so much depends on the material being washed, the height of the elevators, and different local conditions; but there is not the slightest doubt that, whatever the conditions may be, far less power is required for the Elliott than for the piston type of washer. There are several Elliott washers now working which treat 1,000 tons per day of 10 hours and are driven entirely by a 90 horsepower engine, the plant including duff-screens, sieves, elevators, pumps, scraper-chains, water-screens, disintegrators, etc.

The working expenses, power, labour in washing, clean out settling tank, repairs, belting, oil, etc., vary from 1d. to 1 per ton, excluding the sinking fund for redemption of capi which may vary from £5,000 for a washer capable of treat 1,000 tons per day of 10 hours, up to £10,000, according to class of building and general elasticity required in the wash

If the dust is well screened out and the coal classified in th sizes, the first up to ¼ inch, the second ¼ inch to ¾ inch, and third over ¾ inch, it will be found that there is practically no f coal in the shale, and that the washed coal, on analysis, shows o ½ to 1 per cent. more than its natural fixed ash, the lo percentage being obtained with coal containing, when unwash 12 per cent., and the higher with coal containing, when washed, 17 to 20 per cent. of ash.

The main advantages and features of the Elliott washer, compared with the piston-type, are as follows:—Low initial c greatly reduced labour-charges, very low repair and maintenan charges, great reduction in motive power, utilization of whole of the duff or dust, minimum of wastage, and maxim of elasticity and efficiency.

Devil Disintegrator.

A very important factor in coking and briquetting is the gri ing apparatus. It is not generally and sufficiently recogni how important a part the grinder plays in the structure of coke. However small the coal may be ground, the uniform of the grain is of vital importance. With the ordinary dou disc bar disintegrator, it is impossible to secure a regular unifo sample, and it will be found that there is always a great vari of dust, of small and larger grain in the product of this type disintegrator, which results in the coke being too badly fissu and broken up.

The devil disintegrator consists of two rings fitted with r of teeth of different sizes arranged in concentric circles, one of rings being fixed and the other revolving, the teeth of the rev ing ring fitting into the interstices of the teeth of the fixed ri By means of a simple attachment on the revolving ring, it car brought closely into contact with, or at any desired distance fr the stationary ring, thus enabling the operator to grind to desired size and ensuring greater uniformity in size of ground than with the bar type of grinder, which is more per

sive in its action and produces a mixture of very fine coal-dust and different sized grains. Coal ground by the devil disintegrator yields coke of a better structure than coal pulverized by the bar-type of disintegrator. There is an arrangement in the devil disintegrator which prevents coherence, an important feature with wet coal, or a mixture of coal and pitch for briquetting. The rings are made of cast-iron well chilled; and they last about 12 months, if the rings are reversed in running when the teeth on one side are ground down. No reserve disintegrator is necessary, but simply a pair of reserve rings, which can be fixed by an ordinary labourer in an hour. The devil disintegrator only requires one belt, it is easily dismounted, and takes less power than an ordinary disintegrator.

Many may wonder why so many foreign complicated and costly washers, costly both as regards initial outlay and cost of running and maintenance, have been and are being erected in Great Britain, when so cheap and effective a washer has been designed and constructed in this country. Germany was the pioneer of modern coal-washing, and brought to the front the economic questions of utilizing waste by manufacturing briquettes and recovering bye-products, using the waste-gas for power purposes, and classifying coal so as to render it suitable for each class of consumer; in fact there is no doubt that German engineers were at work in this direction, and recognized the importance of utilizing waste, etc., many years before their British colleagues. This fact has given German constructors a certain advantage, and many British colliery managers have the impression that anything up-to-date in this particular line can only be procured abroad. This may have been the case 10 years ago, but certainly not to-day.

The CHAIRMAN (Mr. W. G. Phillips) said that the arrangement described by Mr. Greaves appeared to have many merits. It utilized not only coal, but other stuff, to which, in the ordinary state of the market, customers objected. He had much pleasure in moving a hearty vote of thanks to Mr. Greaves for his paper.

The resolution was unanimously agreed to, and the discussion was postponed to a future meeting.

DISCUSSION OF MR. W. C. MOUNTAIN'S PAPER ON THE "COMMERCIAL POSSIBILITIES OF ELECTRIC WINDING FOR MAIN SHAFTS AND AUXILIARY WORK."*

Mr. MAURICE DEACON said that he was not going to criticize Mr. Mountain's paper, because he agreed with it. He thought that the gratitude of the members was due to Mr. Mountain for coming forward in such a pure engineering spirit and telling them not to use electrical winding where steam-power could be applied direct, although such advice was opposite to his interests.

Mr. G. J. BINNS moved a vote of thanks to Mr. W. G. Phillips for his services in the chair.

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* *Trans. Inst. M. E.*, 1906, vol. xxxi., page 329.

THE MINING INSTITUTE OF SCOTLAND.

ANNUAL GENERAL MEETING,

HELD IN THE HALL OF THE INSTITUTE, HAMILTON, APRIL 11TH, 1907.

DR. ROBERT THOMAS MOORE, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The annual report of the Council was read as follows:—

ANNUAL REPORT OF THE COUNCIL, 1906-1907.

The Council have pleasure in submitting their twenty-ninth annual report.

The number on the roll, at present, is as follows:—

Honorary Members	4
Life Members	9
Life Associate Member	1
Members (subscription £2 2s.)	175
Members (subscription £1 5s.)	276
Associate Members	31
Associates	13
Students	18
Non-federated Life Member	1
Non-federated Members (subscription £1 1s.)	12
Non-federated Members (subscription 10s. 6d.)	4
Total ...	544

This number compares with that of last year as follows:—

On the roll at April, 1906		524
Added during the year		48
Total ...		572
Died	4	
Retired	10	
Cut off through non-payment of subscriptions	14	28
At present on the roll		544

This statement shows a net increase of 20 during the year.

The following papers, with discussions thereon, have been before the members and published in the *Transactions*:—

"Electric Power-station, Winding-gear and Pumping-plant of the Oil Company, Limited." By Mr. James Caldwell.
"Acetylene Safety-lamps." By Mr. L. H. Hodgson.
"The Wolf Safety-lamp." By Mr. L. H. Hodgson.
"Non-rotating Wire-ropes, and Tests of Wire-rope Attachments." Ernest King.
"Notes on the Detection and Estimation of Inflammable Gases in M Means of Flame-caps." By Mr. Charles Latham.
"The McCutcheon Gas-detector." By Mr. Robert McLaren.
"Heading by Longwall Machines." By Mr. Sam Mavor.
"Effects of Acceleration on Winding-torques, and Test of Tarbrax I Winding-plant." By Mr. George Ness.
"The Gold-field of Paracatú, Minas Geraes, Brazil." By Mr. Hugh I
"A Diamond Hand-boring Machine." By Mr. John B. Thomson.
"Tests of a Mine-fan." By Mr. John B. Thomson.

Through the kindness of the Tarbrax Oil Company, L the members had an opportunity of inspecting the installation at Tarbrax oil-works in June last, a special being the electric winding, which is the first of its k Scotland. There was a large turn-out, and the excursi very successful.

On the occasion of the visit of the American Instit Mining Engineers to this country in August last, an tunity was afforded, in conjunction with the West of Sc Iron and Steel Institute, of entertaining them to an ex by chartered steamer on the Clyde, a mark of courtesy was greatly appreciated by the visitors. On the evening same day, the Lord Provost and Magistrates of Glasgo a reception in the municipal buildings to the joint Ins

The issue of a new catalogue of the Library, at the beg of the year, has served to quicken interest in the large col of books which the Institute now possesses, and which is constantly added to by purchase and exchange.

The donations to the Library during the year, in a to those received by exchange, are as follows:—

Donors.	Donations.
Mr. Robert McLaren.	Mines' Reports and Statistics 1904-1905, 2
Mr. J. T. Robson.	Mines' Inspector's Report, 1905, Swansea D
Mr. J. M. Ronaldson.	Mines' Inspectors' Reports, 1905, 13 volumes.
Mr. G. Henriksen.	Pamphlet on Sundry Geological Problems.
Messrs. John Watson, Limited.	Case with the complete core of a diamond b the Splint seam to the Drumgray coal-se Hamilton.

The financial condition of the Institute is satisfactory, as shown by the Treasurer's accounts.

There have been nine meetings of Council during the year.

The report was unanimously adopted.

The annexed abstract of the Treasurer's accounts was read and adopted.

The following gentlemen were elected:—

MEMBERS—

Mr. CHARLES ATHERTON ATCHLEY, c/o Messrs. G. Harland, Bowden & Co., Baltic Chambers, Glasgow.
Mr. JAMES COOPER, 1 Roseneath Terrace, Edinburgh.
Mr. ANDREW SNEDDON HOWIE, Messrs. Backus & Johnston Co., Casapalca, Peru.
Mr. THOMAS M'MEEKIN, Forth View Cottage, Wallyford, Musselburgh.
Mr. JOHN W. M'TRUSTY, Technical College, Wigan.
Mr. JOHN SNEDDON, Cornsilloch Colliery, Netherburn.

ELECTION OF OFFICERS, 1907-1908.

Office-bearers for the session 1907-1908 were elected as follows:—

PRESIDENT:

Dr. ROBERT THOMAS MOORE, 142, St. Vincent Street, Glasgow.

VICE-PRESIDENTS:

Mr. ARCHIBALD BLYTH, Lochside, Hamilton.
Mr. JAMES HAMILTON, 208, St. Vincent Street, Glasgow.
Mr. THOMAS H. MOTTRAM, 6, Kelvinside Gardens, N., Glasgow.
Mr. THOMAS THOMSON, Fairview, Hamilton.

COUNCILLORS:

Mr. JAMES ARMOUR, St. Abbs, Leven.
Mr. THOMAS ARNOTT, 12, Garrioch Drive, Kelvinside, Glasgow.
Mr. JAMES BAIN, The Whins, Alloa.
Mr. HARRY D. D. BARMAN, 21, University Gardens, Glasgow.
Mr. ADAM BROWN, Allanton Colliery, Hamilton.
Mr. JOHN T. HOWAT, Stobbs House, Kilwinning.
Mr. WILLIAM HOWAT, North Motherwell Colliery, Motherwell.
Mr. DOUGLAS JACKSON, Coltness Iron-works, Newmains.
Mr. THOMAS J. JAMIESON, Motherwell Colliery, Motherwell.
Mr. JAMES M'PHAIL, Bog Colliery, Bothwell.
Mr. JOHN MENZIES, Auchinraith Colliery, Blantyre.
Mr. J. BALFOUR SNEDDON, Oakbank Colliery, Mid Calder.

THE TREASURER IN ACCOUNT WITH THE MINING INSTITUTE OF SCOTLAND, FOR THE SESSION 1906-1907.

RECEIPTS.	£	s.	d.
To Balance from Session 1905-1906	535	2	3
„ Members' Subscriptions—			
Arrears	1	5	0
Balance	0	4	0
4 Members, Session 1905-1906 at 42s. 0d.	8	8	0
2 Members, „ „ „ 25s. 0d.	2	10	0
170 Members, Session 1906-1907 „ 42s. 0d.	357	0	0
1 Member. „ „ to account	1	5	0
263 Members, „ „ at 25s. 0d.	328	15	0
12 Members, „ „ „ 21s. 0d.	12	12	0
4 Members, „ „ „ 10s. 6d.	2	2	0
30 Associate Members, „ „ 42s. 0d.	63	0	0
12 Associates, „ „ „ 25s. 0d.	15	0	0
16 Students, „ „ „ 25s. 0d.	20	0	0
6 Members, Session. 1907-1908 „ 42s. 0d.	12	12	0
2 Members, „ „ „ 25s. 0d.	2	10	0
„ Extraordinary income, being contributions to Guarantee Fund, for the entertainment of the American Institute of Mining Engineers	40	6	6
„ Rents of hall	8	18	0
„ *Transactions*, etc., sold	0	9	10
„ Interest	11	6	3
	£1,423	5	10

PAYMENTS.	£	s.	d.	£	s.	d.
By The Institution of Mining Engineers ...				498	5	7
„ Printing and stationery				62	16	7
„ Books and book-binding				24	14	11
„ Rents of halls				64	8	0
„ Electric lighting and assessments ...				9	11	5
„ Stamps, telegrams, carriages, etc. ...				12	15	11½
„ Sundry payments				9	18	8
„ Extraordinary expenditure, being amount of guarantee for entertainment of the American Institute of Mining Engineers				35	0	0
„ Salaries				101	8	0
„ Cleaning of hall				8	0	6
„ Travelling expenses of representatives on the Institution Council				47	0	0
„ Cash in Post Office Savings Bank ...	129	14	8			
„ „ in Commercial Bank	419	8	5			
„ „ in Treasurer's hands	0	3	1½			
				549	6	2½
				£1,423	5	10

Hamilton, March 28th, 1907.—Examined, compared with vouchers, and found correct.

DISCUSSION OF MR. JOHN B. THOMSON'S PAPER ON "TESTS OF A MINE-FAN."*

Mr. JAMES BLACK (Airdrie) said that Mr. Thomson had made a few mistakes in finding the efficiency of the fan. In the first test, the indicator-diagrams, to determine the average steam-pressure in the cylinder, were taken when the engine was running at 90 revolutions per minute; and the necessary measurements to determine the horsepower in the air were taken when the engine was running at 92 revolutions per minute. Of course it was necessary, before Mr. Thomson could calculate the efficiency of the fan, that he should find the horsepower in the air and the horsepower in the steam-cylinder when the engine was running at the same number of revolutions in both cases. These calculations could have been accomplished in two different ways, either by finding the horsepower in the steam-cylinder when the engine was running at 92 revolutions per minute, or by finding the horsepower in the air when the engine was running at 90 revolutions per minute. Mr. Thomson selected the latter method, and in making this adjustment he incorrectly assumed that the horsepower in the air varied directly as the revolutions of the engine. Actually the horsepower in the air varied directly as the cube of the revolutions of the engine, and consequently the accuracy of Mr. Thomson's result was seriously affected. Thus, instead of the efficiency being 87·8 per cent., it was 83·98 per cent. He could not say whether there was a similar mistake in the other tests, as the information was not available in the paper. However, the valuable deduction could be made that, in finding the efficiency of a fan, the various operations should always be carried out simultaneously.

He (Mr. Black) thought that another mistake had occurred in the third test: the air-current in that test was measured underground, and the water-gauge was 2·03 inches in the fan-drift, and 1·16 inches underground; Mr. Thomson stated that "the water-gauge due to the differences of temperature, calculated on the depth of the Main coal-seam, was 0·11 inch; and the actual water-gauge due to the fan was (2·03 − 0·11 or) 1·92 inches." Mr. Thomson had erroneously assumed that the reading of the water-gauge on the fan-drift included the water-gauge due to the differences of temperature in the shafts. The "natural"

* *Trans. Inst. M. E.*, 1906, vol. xxxii., page 295; and vol. xxxiii., page 58.

water-gauge did not increase the efficiency of th
although it assisted the ventilation of the mine, but th
an entirely different matter. Mr. Thomson was actua
crediting the fan with work which it had legitimately
plished, and consequently he arrived at an inaccurate
and, instead of the efficiency being 64·2 per cent., it was a
67·8 per cent. He (Mr. Black) could not understand w
Thomson in his summary did not notice that somethi
wrong with one or other of his results, because in the fi
second tests the water-gauge due to the differences of sh
perature were eliminated; and it was taken into consider
the third test. Had he been justified in this exclusion
test, surely he would have been justified in all, unless the
temperature in both shafts was the same, and this, of cou
not probable. This error affected the efficiency in the
test; and, instead of the result being 86·5 per cent.,
actually 91·3 per cent.

Mr. JOHN B. THOMSON, in thanking the members for t
in which they had received his paper and more especi
gentlemen who had taken part in the discussion, said that
been specially interested in the communication by P
Rateau, who mentioned that the measurements ought
been made with a Pitot tube. He had read Prof. Rateau
on "Experimental Investigations upon the Theory of th
Tube and the Woltmann Mill,"* and found that the wate
tube should have been held like the Pitot tube, namely,
the air. If that had been done, the efficiency of the fa
have been reduced, as Prof. Rateau had remarked, fro
86 to 55 per cent.; but that did not explain the great
ence between the measurements of the air in the m
on the surface. The fan-drift was not quite level: it
about 1 in 6; and Mr. T. H. Mottram vividly described th
that took place in that drift. Mr. James Black took ex
to the way in which the air had been measured, and thou
the nine spaces, into which the fan-drift was divided, v
large; but 4 square feet might be considered as a small
area. Mr. Black also took exception to the system of
as against dividing the fan-drift into squares with wires an

* *Trans. Inst. M. E.*, 1899, vol. xvii., page 124.

the anemometer on the end of a rod. The rod could be used in two ways: (1) The anemometer could be mounted on the end of the rod, so that the observer must stand behind it and move himself about with it keeping the rod level; but it was difficult to keep the anemometer parallel to the section of the fan-drift, and an eddy was set up by the body of the operator being placed so near the instrument. (2) The anemometer could be mounted on the side of the rod, and the operator would then stand in the section where the air was being measured. This method was subject to several difficulties, especially if the fan-drift was large with varying velocities of the air in the different spaces. Great difficulty was experienced in keeping the anemometer in the section, when changing from space to space. Further, the operator standing in the section reduced its area and set up eddies. He thought that the system of shelves, taken off to a knife-edge facing the current, was the better method, as the fan-drift was entirely clear of men during the 5 minutes' duration of the reading in each space. It took a very short time to start the anemometer and for the operator to retire from the section. It was evident that the efficiency of a fan was not easily determined when measuring the air so near the ear of the fan, and more especially in the case of small quick-running fans.

The PRESIDENT (Dr. R. T. Moore) said that the question of measuring the quantity of air going into the fan-drift was a difficulty which many members had experienced. The difficulties, brought out in the course of the present discussion, illustrated the advantage of bringing subjects of this kind before the notice of the members.

The discussion was closed, and a hearty vote of thanks was awarded to Mr. Thomson for his paper.

DISCUSSION OF MR. SAM MAVOR'S PAPER ON "HEADING BY LONGWALL MACHINES."*

Mr. R. W. DRON (Glasgow) said that he could not speak from his own experience of the bar-type of machine, but in regard to that type of coal-cutting machine further evidence would be required before accepting all the claims put forward on its behalf.

* *Trans. Inst. M. E.*, 1907, vol. xxxiii., page 65.

The idea of opening out work with a coal-cutting machi being generally adopted. Mr. Mavor's paper was found the assumption that the bar cutter could do something could not be done with any other coal-cutter; and he ren that "the feature of the longwall bar machine, especially ing it for heading work, is the arrangement which enable cut-in at one end of the face and cut-out at the other avoiding the necessity for stable-holes."* Perhaps some bers, who had bar coal-cutters and were doing without holes, would give their experience. Enquiries addres engineers, who were using bar cutters, brought forth the "stable-holes are made, the same as for any other mac Table I.† showed that in a place 90 feet wide an area of 60 yards was undercut per shift of 8 hours; and that the tot was £1 13s. 9d. per shift, which comprized £1 4s. for thre at 8s. per shift, and 9s. 9d. for power-supply, etc. He could n follow whether Mr. Mavor meant that these three men we ployed for 8 hours in this 90 feet place, because Mr. Mav said that it could be done in 4 hours.‡ (1) If the work wer in 8 hours, Mr. Mavor's machine would cut across the fac hour at the rate of 1½ feet per minute; and, consequently, 7 and a proportionate part of the £1 13s. 9d. were employed ir ing the machine and cutting the corners. (2) If the worl done in 4 hours, allowing a cutting speed of 1½ feet, 1 hour be occupied in cutting and 3 hours and three-fourths of £1 1 would be spent in turning the machine and forming the c And, in addition, the man who was working the corne breaking down the coal to this nice curve would requir ment at the rate, at least, of 1d. a ton extra on that place, the coal was exceptionally favourable. Consequently, th for the corners was practically the same with the bar t machine as with the disc type. These figures, however, d altogether vitiate Mr. Mavor's main contention, that the lo coal-cutting machine could be utilized for driving heading (Mr. Dron) was driving faces with widths of 200 feet or s an ordinary disc machine. Where the holing was reasonabl a channelling machine would not give any benefit in d narrow headings, but it would show great economy when

* *Trans. Inst. M. E.*, 1907, vol. xxxiii., page 67.

† *Ibid.*, page 68. ‡ *Ibid.*, page 72.

pared with hand-labour in a hard holing. Mr. Mavor's was a valuable paper, and he hoped that criticism and further information would be supplied by members who were using the bar machine.

Mr. JOHN BLAKE (Hamilton) said that the bar coal-cutter at Eddlewood colliery cut in and cut out. The machine was turned on the last road-head, and usually took 35 minutes. The best speed, for 8½ hours actual cutting, was 450 feet of longwall face cut to a depth of 3 feet.

Mr. THOMAS STEVENSON said that at Earnock colliery the bar machine cut out its own stables both at the bottom and at the top. The machine was turned on the last road-head, and took about 45 minutes, but it depended on the pavement. Places at the rib-side were not paid anything extra: this work being paid at the same rate as the rest. The bar machine seemed to suit their requirements better than the disc machine because the coal was inclined to go down. With the disc machine, two men are required to shovel back. There was no difficulty in the bar machine cutting into any level, cutting straight and without any stables.

Mr. THOMAS ARNOT (Glasgow) said that he had used the bar machine in opening two machine-sections by two branching headings with about 150 feet of face. The machine, with a 6 feet bar, could easily cut 150 feet to a depth of 6 feet in 8 hours. Some difficulty was experienced as the coal gave way; and, at the same time, they had difficulty in stripping. It took a little time to turn the machine, probably about an hour. It took a little time, too, to get the bar into position, depending on the length of the bar and the material into which it was cutting. The bar machine was a good one for opening up two sections simultaneously and quickly at a small cost.

Mr. THOMAS THOMSON (Hamilton) said that he had made a turn-table, as he thought that it would be of great advantage and save time in turning the machine: but he found that it occupied much space, the machine being 14 feet in length; and the roof would not stand over so great a width. However, a machine could be turned in 30 minutes; he thought that this was speedy work, and was content to work without a table.

Mr. JOHN MCLUCKIE (Larkhall) said that he was much s prised at the remarks of Messrs. Thomson, Blake and others w said that the bar machine holed its own stables. Mr. Mavor's d grams showed that part of the stable must be cut out at the en and, wherever Mr. Thomson turned the bar machine, some p must be left. And further, if Mr. Thomson turned the mach at the nearest road to the end, it must cut up to the corner w the bar in front to finish the run; by so doing, he adopted method to which he strongly objected of cutting with the in front. The bar machine was giving good results in longw heading, in the manner suggested by Mr. Mavor. If it was case that no payment was made for the corners, then the machine was in a very favourable position compared with disc machine. Mr. Mavor stated that the wages of the worki were £1 4s. for three men; but, in the Larkhall district, wh the seams were very thin and the work not too comfortable, machineman, and the second and third hands expected substan wages. He thought that Mr. Mavor would require to enhance wages of his workmen.

MR. SAM MAVOR said that the claim of the longwall machine to inclusion in the list of heading machines was an justified by its performances, examples of which were given the paper. It was true that the disc-type of machine could be used for advancing places about 90 feet wide; but it must quite obvious to members who had experience in handling b disc and bar machines, that the latter had special advanta when applied to work of that kind. The point that he wis to bring out in his paper was that the application of the machine in the method described (holing 6 feet deep and cutt in and cutting-out at the ends of the face) allied rapidity advance with the economies of longwall working. The d culty instanced by Mr. Arnot could be easily overcome by creasing the diameter across the cutters near the root of the The effect of this slight modification was to increase the he of the cut at the front, giving the coal a greater distance to c and allowing it to fall forward. This method of tapering cut was used in undercutting thick seams in a number of lieries in England. Formerly, when the machines were mou on rails, turn-tables had been used for turning the machi

but, since the introduction of skids, it was found that the machine could be more easily turned without a turn-table. Mr. Thomson had said that the machine on skids was turned in about 30 minutes, and this time could not be greatly decreased. The wages quoted in Table I. were those actually paid for the minimum shift of 8 hours. The time required to cross the short face was less than a shift; and, therefore, the whole work might be profitably contracted, and the machineman could assist in filling coals or at stone-work

The discussion was then closed, and a hearty vote of thanks was awarded to Mr. Mavor for his paper.

Mr. Henry Simonis gave a demonstration of the use of the Aerolith liquid-air rescue-apparatus.*

Mr. John F. K. Brown read the following paper on "A Stretcher for Use in Mines":—

* "Liquid Air and its Use in Rescue-apparatus," by Mr. Otto Simonis, *Trans. Inst. M. E.*, 1906, vol. xxxii., page 534.

A STRETCHER FOR USE IN MINES.

By JOHN F. K. BROWN.

There can be no doubt that, in many cases, the pres methods of removing injured men from the working-faces very inadequate.

The proposed stretcher is designed to carry men to the sh bottom in comparative ease and comfort. It consists of sev strips of canvas or sail-cloth, 4' inches wide, arranged as sh in fig. 1 (plate iv.), all the bands being strongly sewn toge at the points where they cross each other. It is intended t the bands or end-supports, *b*, *b*, shall be fastened under bands, *a*, *a*, with hooks and eyes similar to those shown in 8 and 9, so as to admit of raising and lowering either the h or the feet, as the case may be, by fastening the hook int higher or lower eye sewn to the bands, *a*, *a*. The princ dimensions are shown in fig. 1, which represents the suppor it appears when laid out on the ground. The size represer is suitable for use on a hutch 4½ feet long, 2 feet deep and 3 wide. Figs. 2 and 3 show how the stretcher is attached to standards of any bogie, or to the sides of any hutch in the The cross-bands, *a*, are arranged so as to give support to a n of average height and to allow of a hammock-formation w fastened to its supports; and, if greater ease be required, c may be flung over the spaces between the bands. The e pieces, *b*, *b*, for the support of the head and of the feet, are m of somewhat stiffer canvas, and are turned upward so as to as in affording horizontal as well as vertical support. The wei of the man stretched out will be sufficient to keep them exten a foot or less beyond the main supporting bands, *a*, *a*, and the same time give support to the patient. The stretche intended principally for use with a bogie, and special caps provided for fastening over the standards as shown in figs. 4 5: these caps being varied in design to suit the standards different bogies. It may also be used, either with a door-hu

he advantages claimed for this stretcher as compared with rdinary stretcher are as follows:—(1) It is very much r for the injured person, being of the nature of a hammock; nsequently, it does not aggravate many injuries which might wise become serious; (3) as a result of this greater ease, the can be safely run at a greater speed to the shaft-bottom and time is saved; (4) it is easily put together; (5) it can be with either a hutch or a bogie, or as an ordinary stretcher; can easily be folded in a small space and carried; and (7) be hung on a nail, anywhere, ready for fixing to the bogie.

A. HANLEY read the following paper on "The Hanley

THE HANLEY CAGE GUARDIAN.

By ALBERT HANLEY.

The cage guardian is intended to guard the cage against dangers arising from excessive speed, unbalanced forces, jumping the guides, breakage of guides and breakage of the winding rope, on whatever type of guide and weight of cage it may be used.

FIG. 5.—GUIDE-ROPE, 4 INCHES IN CIRCUMFERENCE, BENT BY THE ACTION OF THE HANLEY CAGE GUARDIAN AT DEAN LANE COLLIERY.

In a practical application at Dean Lane colliery, Bristol, and other collieries, the guardian has ridden freely at speeds up to 75 feet per second, rendered the cage more steady, and exerted test-grips varying from 4 cwts. to 10 tons. Figs. 1 to 4 (plate .) show two sets in practical application at Dean Lane colliery. Each set consists of the parts A, B, C, D, E, F and H: the link or chain, B_1 or B_2; the weight, H, and the horizontal links connecting two or more sets are not absolutely necessary. The horizontal arm, A, the shackle, D, the shoe, F, and the strap, C, form a solid built-up rod. The end of the shackle, D, is attached to the cage-shackle, I, and the shoe, F, moves around, but not on the guide, G. The strap, C, attaches the shoe, F, to the arm, A. The arm, A, forms a connecting rod joining the centre-line of the winding forces to the centre of the guide-path. The adjustable link, B, is attached to the arm, A, and to the rope, at any point, 12 inches or more, above the shackle, D, which

ıched to the cage-chains, the coupling-chain, the rope-
rope-pin. The link, B, may be attached to the rope-
ort coupling, or any other part above the shackle, D.
ıtal arm, A, and the link, B, form two sides of a tri-
hird and guiding side being the rope, J, or other point
re-line of the winding forces. These parts may be
r thickness or strength.

rope, J, becoming detached, the cage-shackle, I,
the shackle, D (fig. 1, plate v.); and because the
greater
ıckle, D,
shoe, F,
ıtal arm,
a sloping
the shoe,
ıe guide,
human
plate v.),
shackle,
a hinge
v.).
ıount of
ependent
ıter than
of the
grip is
o a pull
er and a
he lower
guides,
ıuch are
, girder,
pe; and
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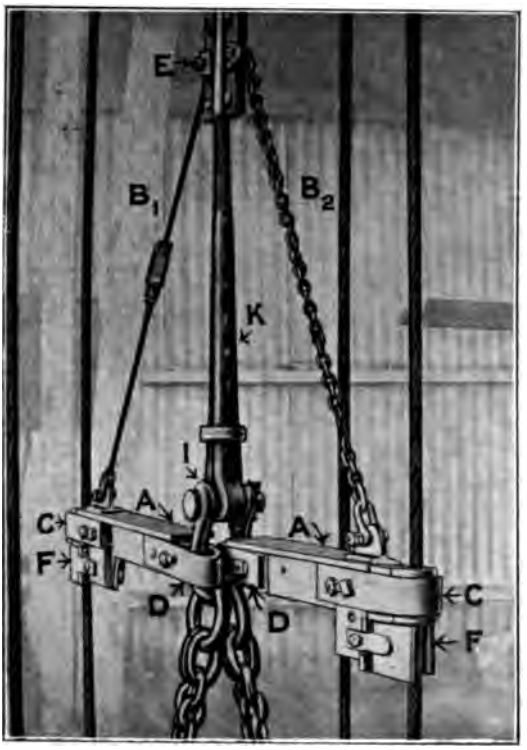

FIG. 6.—TWO SETS OF THE HANLEY CAGE GUARDIAN ON THE DOWNCAST SHAFT, DEAN LANE COLLIERY.

prevented by a special design, and thrust only is
mited to suit the safe deflection of the particular
the friction of the thrust would hold the cage. The
ig. 1, plate v.) are so designed and fitted that the

angle of inclination is limited to a point when the shackles, D, become locked against the cage-shackle, I (fig. 4, plate v.), so that the rope-guides shall only be stretched and bent to an amount dependent on the particular guide (fig. 5).* If that angle is not sufficient to hold the cage (as in breakages on the downward journey), the appliance slides on the guide until the friction of the downward sliding movement consumes the surplus energy of the cage.

As many as eight sets of this appliance may be used on as many guides; or a special safety-guide or guides may be erected, and one set of the guardian of suitable dimensions used for the cage.

The appliance does not exert any false grip when a cage is dropped slack and picked up rapidly. The pressure, to cause grip, must be exercised at the shackle, D; and there is no loosening action on the bolts.

The appliance has the peculiarity that, although the horizontal arm, A, acts as a free rod, as soon as pressure comes on the shackle, D, it behaves as if it were a lever; and practically it acts as a lever, without a fulcrum, attached to the cage. There are no springs. The appliance is not attached, and at the first part of the moment it is independent of the cage, which merely tightens the grip sufficiently to hold itself.

The two sets at Dean Lane colliery (fig. 6) weigh 150 pounds, or 35 pounds per ton of loaded cage; and each set is sufficient to hold the cage. The sliding action in a test, 7 feet in 1½ minutes or 280 feet per hour, slackened as the appliance slid down the guide-rope and then the cage stopped.

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* Rope-guides, similarly bent, have been readily straightened in less than 30 minutes; and in one special case, where the stress of the grip was 82 cwts., 60 per cent. of the breaking strength of the guide, scarcely a trace of the previous bend was observable.

THE SOUTH STAFFORDSHIRE AND WARWICKSHIRE INSTITUTE OF MINING ENGINEERS.

GENERAL MEETING,
HELD AT THE UNIVERSITY, BIRMINGHAM, APRIL 16TH, 1907.

MR. F. A. GRAYSTON, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting and of Council Meetings were read and confirmed.

The following gentlemen were elected:—

MEMBER—
Mr. JONATHAN HUNTER, Colliery Manager, Cannock, Staffordshire.

ASSOCIATE MEMBER—
Mr. W. DUFF GIBBON, King's Heath, Birmingham.

DISCUSSION OF MR. F. C. SWALLOW'S PAPER ON "BOILERS FOR COLLIERY PURPOSES."*

Mr. J. T. ONIONS said that the author had quoted instances where the consumption of fuel had been as low as 1½ per cent. of the output, and others where the consumption was as high as 11 per cent.: but both examples were extreme cases, the former being exceptionally so. His own experience with boilers of the Lancashire type had been an average of 6 per cent., which might be said to be a low one for the district. He had recently perused a colliery-lease which only allowed a colliery-consumption of 4 per cent. free from royalty. He desired to ask the author what had been his experience with the deposition of mud in the tubes and mud-drum of the water-tube boiler, and particularly whether mud was deposited in the vertical tubes.

Mr. S. F. SOPWITH thought that so low a consumption as 1½ per cent. could only be attained under the most favourable con-

* *Trans. Inst. M. E.*, 1906, vol. xxxii., page 320.

ditions, such as those where coking coal was manufa
coke and the boilers were fired by the gases drawn
ovens. His own experience in the Cannock Chase d
been an average all the year round of about 8 per c
output of 500,000 tons per annum—in summer (when
was less) from 9 to 10 per cent., and in winter from
cent.

DISCUSSION OF MR. A. HANLEY'S PAPER
HANLEY CAGE GUARDIAN."*

Mr. Albert Hanley exhibited and described
guardian, an appliance designed to guard against a
the cage from the breaking of the winding-rope. R
dents proved once more how it behoved colliery-offici
every precaution for preventing loss of life; and th
possibility of hasty and restrictive legislation unless
dents were prevented.

The President (Mr. F. A. Grayston) said that t
appliance appeared not to act too quickly, as was the c
appliances designed to prevent winding accidents.
sidered that the invention should be put to more pr
thorough tests, under ordinary working conditions, th
been made. He was inclined to think, if the rope we
near the surface when the cage was at any depth, that
quences would be serious, owing to the heavy weig
falling upon and around the cage and appliances,
latter had time to suspend the cage.

Mr. S. F. Sopwith asked what was the actual gre
on a rope-guide that had been recorded on the break
rope on the downward journey, and whether existi
which were not fitted for that purpose, were sufficien
stand the additional strain?

Mr. Hanley said that it did not follow that the s
appliance stopped where it first gripped; and in o
slipped 7 feet in 1½ minutes. The shoe touched the g
2 degrees out of the perpendicular, and commenced to

* *Trans. Inst. M. E.*, 1907, vol. xxxiii., page 164.

it became 6 degrees. The movement and grip of the appliance was not a sudden fall and a sudden grip at the stopping position. When the rope was detached, the cage-shackle, I, and the cage-weight pressed on the shackle, D, causing the arm, A, to move in an increasingly inclined position, the motion gradually slackening and retardation gradually increasing till the cage and the appliance stopped.* The point of stoppage and the distance of sliding on the guide depended on the cage-weight and the character of the guide. The distance of sliding on the guides could be lengthened or increased relatively, but sliding was allowed in practice so as to enable the appliance to utilize the kinetic energy of down-breakages. He did not think that a broken rope, even if 500 feet long, would interfere with the safety of the appliance, as the apparatus tended to throw it on one side and it would then fall, to some extent, clear of the cage. The tests had been made with a detaching-hook to sever the rope. The greatest stress on a guide had been 10 tons. A special guide could probably be fitted for use with heavy cages, where it was not desirable to use the working guides for safety purposes. A special safety guide would prevent any excessive lateral swing of the cage if a working guide were broken; and it could be used to replace, temporarily, the broken guide. The use of a special safety guide would provide extra stability to the cage, especially in the case of long cages sliding on wood or iron guides.

Mr. Alexander Smith said that he had great sympathy with inventors, as they had considerable difficulty in putting an invention of this kind to a proper practical test, colliery owners being very unwilling to carry out experiments and tests with their plants under working conditions. There was certainly one good feature about the apparatus, namely, that it was slow in action: the fault of similar safety-appliances being their sudden action, a remedy almost as bad as the disease.

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* *Trans. Inst. M. E.*, 1907, vol. xxxiii., page 165.

MANCHESTER GEOLOGICAL AND MINING S

GENERAL MEETING,
HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBER
5, JOHN DALTON STREET, MANCHESTER,
FEBRUARY 12TH, 1907.

MR. CHARLES PILKINGTON, PRESIDENT, IN THE CHA

The following gentlemen were elected, having b viously nominated:—

MEMBER—
Mr. HENRY BATSON BEALES, Mechanical and Electrical Enginee Street, Manchester.

ASSOCIATE MEMBER—
Mr. FRIEDRICH SCHEMBER, 9 Liechtenstrasse, Vienna.

DISCUSSION OF MR. OTTO SIMONIS' PAP "LIQUID AIR AND ITS USE IN E APPARATUS."*

Mr. OTTO SIMONIS (London) demonstrated and expl aerolith, a liquid-air rescue-apparatus. He (Mr. Otto was not a mining engineer, but a fire engineer; and i the purpose of combating smoke that the apparatus designed. The apparatus was now used at Baron Ro coal-mines in Austria, and by the London Fire Bri Baron Rothschild's mines, a plant had been installed of £1,400 for the production of liquid air; about 2 per hour were made, and in addition compressed ox produced with the same plant. This plant proved to b big, as they had found employment for the liquid air in of ways.

The PRESIDENT (Mr. Charles Pilkington) expressed that the aerolith apparatus would easily get damag

* *Trans. Inst. M. E.*, 1906, vol. xxxii., page 534.

worn on the back; because, in a mine after an explosion, the wearer would have to crawl on his hands and knees, and the knapsack or bag would be rubbed against the roof. He suggested that the clock, placed at the top, and intended to warn the wearer when the stock of liquid air was nearly exhausted, might be placed, if possible, in a less exposed position.

Mr. Otto Simonis replied that the bag was not an essential part of the apparatus, as it could be removed, and the apparatus would still work efficiently. He, however, preferred to use the bag, as it afforded an auxiliary reservoir for extraordinary cases. The man who was using the apparatus would become aware in due time of his danger, by feeling the bag and by the diminution of the volume of air passing through his lungs.

Mr. John Gerrard (H.M. Inspector of Mines) asked what quantity of air was left in the knapsack after the clock had given warning.

Mr. Otto Simonis said that the wearer could set the clock to give warning when the supply was half done, or when it would be exhausted in another half-hour. Bottles filled with liquid air could be taken into the mine and kept there for use in emergencies.

The President (Mr. Charles Pilkington) said that he had seen many appliances designed for rescue-purposes. He was a member of a committee which had to deal with this particular subject, and there were possibilities in this apparatus that, in his view, were almost better than anything else he had seen. He was favourably impressed with it, but he wanted to see it tested in rough work. The aerolith apparatus was very much lighter than other kinds, and he hoped to see it severely tested at one of the rescue-stations. He thanked Mr. Simonis, on behalf of the members, for giving this demonstration of its use.

Mr. George H. Winstanley, in moving a vote of thanks to Mr. Simonis, said that he had for a long time taken a deep interest in the question of rescue-apparatus and read a paper ten years ago before the Society in which, curiously enough, he strongly advocated the establishment of properly-equipped

MANCHESTER GEOLOGICAL AND MINING SOCIETY.

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MEMBER—
Mr. HENRY BATSON BEALES, Mechanical and Electrical Engineer, 64, Cross Street, Manchester.

ASSOCIATE MEMBER—
Mr. FRIEDRICH SCHEMBER, 9 Liechtenstrasse, Vienna.

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Mr. OTTO SIMONIS (London) demonstrated and explained the aerolith, a liquid-air rescue-apparatus. He (Mr. Otto Simonis) was not a mining engineer, but a fire engineer; and it was for the purpose of combating smoke that the apparatus was first designed. The apparatus was now used at Baron Rothschild's coal-mines in Austria, and by the London Fire Brigade. At Baron Rothschild's mines, a plant had been installed at a cost of £1,400 for the production of liquid air; about 5 gallons per hour were made, and in addition compressed oxygen was produced with the same plant. This plant proved to be not too big, as they had found employment for the liquid air in a variety of ways.

The PRESIDENT (Mr. Charles Pilkington) expressed the fear that the aerolith apparatus would easily get damaged when

* *Trans. Inst. M. E.*, 1906, vol. xxxii., page 534.

worn on the back; because, in a mine after an explosion, the wearer would have to crawl on his hands and knees, and the knapsack or bag would be rubbed against the roof. He suggested that the clock, placed at the top, and intended to warn the wearer when the stock of liquid air was nearly exhausted, might be placed, if possible, in a less exposed position.

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rescue-stations throughout the coal-fields of Great Britain.* The aerolith apparatus struck him as having features which strongly recommended it as a practical appliance. The great difference between it and many other appliances was its simplicity. The difficulty hitherto had been to dispose satisfactorily of the carbon dioxide, which tended to increase in quantity in the initial volume of air that was breathed over and over again with additions of oxygen. In this apparatus no attempt was made to breathe the same air again; a great advantage would be found, too, in the easily portable character of the bottles of liquid air as against the large steel cylinders of oxygen for replenishing the apparatus in actual use. The former (the bottles of liquid air) could more easily be taken into the mine, and carried forward to some convenient place for the purpose of replenishing the knapsack when necessary; and consequently the rescue-party could carry on their work for a longer period, with less anxiety as to their supply of respirable air.

Mr. JOHN GERRARD (H.M. Inspector of Mines), in seconding the motion, said that he was not going to commit himself to anything more, than to say that, theoretically, the aerolith apparatus appeared to have advantages over the oxygen principle on which other systems depended. He preferred to wait, before pronouncing a definite judgment, until the apparatus had been tested at one of the rescue-stations; and he sincerely hoped that, before very long, they would have a station in Lancashire where they could prove whether this apparatus was practicable or not. Their President was the chairman of the committee that was working for this end, and it was very desirable that its labours should soon be successful. He thought that such an appliance as this might be useful in dealing with underground fires. He held very strongly that there was a field for such apparatus. Fortunately, they did not now have in Lancashire disastrous explosions; but they were constantly having to deal with underground fires, and they had had, in the last few years, several disastrous underground fires which had been most difficult indeed to deal with. It seemed to him that, apart from explosions, there was a field for the use of these appliances in dealing with the extinc-

* *Transactions of the Manchester Geological and Mining Society*, 1897, vol. xxv., page 148.

tion of underground fires. He was sure that they were all very grateful to Mr. Simonis for coming to Manchester, and giving to the Society so full an explantion, because the people of Lancashire liked to be in the van of progress.

The motion was cordially adopted.

Mr. Otto Simonis said that he did not claim that his apparatus was perfect in every detail, such as the type of mouthpiece, etc., and therefore he welcomed any suggestions. He had always held that the rescue-appliances hitherto in use possessed drawbacks which were absolutely against them from a practical point of view. The weight and complication were fatal disadvantages, independently of the fact that there were certain dangers in the use of caustic soda and other chemicals.

Mr. Thomas H. Wordsworth read the following paper on "Cage-lowering Tables at New Moss Colliery":—

CAGE-LOWERING TABLES AT NEW MOSS COLLIERY.

By T. H. WORDSWORTH.

When pits were shallow and only single-decked cages were in use, there was no need for cage-lowering tables; but, as they became deeper, the extra length of time spent in winding, coupled with the great weight of the rope compared with the load lifted, led colliery owners to adopt larger cages. As the size of the pits rendered it impossible to put more tubs on a deck, cages with two, three, four and up to six decks were used.

Where two-decked cages only are used, duplicate landings may be put in both at the surface and underground, and a double set of men may be employed; and this reduces the period of decking to a minimum. In other cases, keps are put in at the pit-bottom; and, by carefully adjusting the ropes, the tubs for each deck are changed simultaneously at the top and the bottom. This system has the disadvantage that, if any hindrance takes place at the top or bottom of the shaft, both sets of men are stopped and the length of time occupied in changing is considerably increased; besides which, the engineman needs a signal from the top and bottom for each deck, and, should he slightly overrun, the cage is likely to be damaged.

The first cage-lowering table seen by the writer was at the West Riding collieries, Normanton, although he believes that they were originally used in Lancashire. The table in use at the West Riding colliery was balanced by weights hanging in a small pit, half of these being hung on the end of the rope and the other half supported on a stage, so that they were picked up after loading the second deck of a four-decked cage. The use of these supplementary weights, whilst reducing the necessary brake-power, caused complications when winding men, and it was only possible to ride men on two of the decks.

The tables now in use at New Moss colliery have been evolved from this: they are so arranged that it is possible to lower

the empty cage and table, and in this way men can ride on all the decks. The balance-weights have been taken out of the pit and put in sight. The apparatus may be divided into three parts:—(1) The table on which the cages alight; (2) the brake-arrangement for giving the hooker-on control of the tackle; and (3) the balance-weights for bringing back the table when the cage is lifted from the bottom.

The table is built of steel joists and channels (figs. 1 and 2, plate vi.). The main frame of the table, A, is formed of two main longitudinal joists, *a* and *b*, 13 feet 3 inches in length, 9 inches deep, 4 inches wide and ½ inch thick, connected at each end by two cross joists, *c*, *d*, *e* and *f*, of the same section, trimmed in and secured by steel angle-irons and rivets, 18 inches from the end. This frame is further strengthened in the centre by steel channel-irons, *g* and *h*, 3½ inches wide and 9 inches deep, placed back to back; and four short joists, *i*, *j*, *k* and *l*, trimmed into these and the end joists form the opening for the balance-rope. There are also four short channel-iron distance-pieces, *m*, *n*, *o* and *p*. Four battens, *q*, *r*, *s* and *t*, 12 inches wide and 3 inches deep are placed longitudinally on this table, so as to form a cushion between the steel cage and the steel table and save wear on the bottom of the cages.

The table, A, is carried by two steel-wire ropes, B and C, 1½ inches in diameter, passing over two pulleys, D and E, 4 feet in diameter, resting on girders running across the pit-bottom. The attachment between the table and the ropes has been arranged so that, by taking out two pins, *u* and *v* or *w* and *x*, at either end of the table, it can be slung from the other rope and hung clear of the cages. In case of cleaning out the sump or of changing the weights, F and G, on the end of the conductors, H, or for any work done below the table, this is a great advantage.

The other ends of the ropes, B and C, after passing round two surge-wheels, I and J, 4 feet in diameter (similar to endless-rope haulage-wheels), and over two pulleys, K and L, 4 feet in diameter, placed about 20 feet above the floor, are attached to steel balance-boxes, M and N, built of angle-irons (3 inches wide, 3 inches deep and ½ inch thick) and plates ½ inch thick. The attachment is made by short sockets, *a*, with pins, *b*, passing through cross bars, *c*, inside the boxes. These boxes are filled

with small scrap-iron, such as chain, bolts, etc., and run in angle-iron slides, *d*, *e*, *f* and *g*.

The brake-wheel, O, 6 feet in diameter and 9 inches wide on the face, together with the two surge-wheels, I and J, is keyed on to a shaft, P, 6 inches in diameter, supported by six pedestals, *a*, *b*, *c*, *d*, *e* and *f*. The brake is of the double-post pattern, with compound levers, *ab*, *cd*, *de*, *fg*, *ghi*, *hj*, *il* and *kl*, the leverage being about 400 to 1; and wooden brake-blocks, *m* and *n*, are used, as they have been found to give the best results. The weight of the levers is balanced by a weight, *q*, attached to a chain, passing over the pulley, *p*.

In working, the winding-engineman drops the cage, Q, on the table, A, which is then in the top position, and at the same time puts the top cage on the keps at the surface. The tubs are then changed in the bottom-deck, and, when the brake-lever is lifted, the weight of the cage, Q, is sufficient to overcome the balance-weights. The hooker-on is then able to stop the cage, with the brake, when the second deck comes level with the landing-plates; and, so on, until all the decks are loaded and the cage and the table are in the position shown in fig. 2 (plate vi.). In this way, by having a small amount of chase or slack on the winding-rope, the hooker-on at the bottom of the shaft is enabled to change his tubs practically as quickly as the change is made on the surface, and no signal is necessary until all the decks are changed and the cage is ready for sending to the surface.

After the cage leaves the bottom, the table is brought back to the top position by the balance-weights.

Too much chase or slack, however, should not be allowed on the winding-rope, as this is objectionable when picking up, and there is also a danger of the detaching-hook coming on the cage-top or down the cage-side, should there be any delay in changing the tubs at the pit-bottom. This difficulty may be overcome by using cage-chains, 10 to 12 feet long; and, with decks only 4 feet deep, it is then possible for the surface-man to deck the whole of the decks of the cage before the detaching-hook falls over the cage-side. On one occasion, when there was too much chase or slack on the rope, the detaching-hook became twisted in the cage-chains, and sheared the copper pin instead of lifting the cage from the bottom.

Old winding-ropes may be used for working the tables, but experience will show, in each case, whether this is the better policy. The writer prefers to use a special flexible rope, as it reduces the liability to stoppage during working hours; and one rope will last three or four years. In cases of overwinding, the table has the advantage that the shock to the bottom cage is considerably reduced. If men were in the cage there would be less liability of their being injured; and it has also been found that the life of the cages is considerably lengthened.

In case of accident or breakdown of any portion of the tackle, the table can be placed in the bottom position, as shown in fig. 2 (plate vi.) and winding continued until the end of the shift or such time as the repairs can be finished. But if the pit has been previously fully occupied in winding, the reduction of the output would vary from 10 to 20 per cent.

It is not suggested that cage-lowering tables should take the place of hydraulic decking-cages, with simultaneous changing for all decks, but there are many instances in faulted and steep districts or thin seams, where it is practically impossible to get sufficient coal to the pit-bottom to keep the winding-engine working full time and so afford a return on the capital necessary to instal hydraulic decking-plant. The writer is of opinion that, where three or four decks are used and the output does not warrant an expenditure on simultaneous changing plant with balance-cages, the cage-lowering table is the best means of dealing with three or four decked cages, especially if a spiral drum be used, as it reduces the number of signals to a minimum and leaves the top and bottom of the shaft practically independent of each other.

The PRESIDENT (Mr. Charles Pilkington) expressed the obligation of the members to Mr. Wordsworth for his paper and the accompanying drawings. It was, no doubt, an important apparatus that Mr. Wordsworth had described, and one that saved a great deal of time in decking. There were several appliances, very similar in character, in use at the Clifton and Kersley collieries, with which he himself was associated; but in the latter case a chain was used, instead of a rope.

Mr. GEORGE B. HARRISON (H.M. Inspector of Mines), in moving that the thanks of the members be accorded to Mr. Wordsworth, stated that he did not remember having seen an apparatus like the one described by Mr. Wordsworth before he came to Lancashire, where, at some pits, there were as many as six decks in the cages, and this apparatus afforded great advantages, particularly to the engineman, who was thereby relieved of a great strain.

Mr. G. H. WINSTANLEY, in seconding the motion, remarked that the apparatus described by Mr. Wordsworth included new details and improvements, which had considerably enhanced the value and interest of his paper. The members present had been interested, and the drawings clearly demonstrated the advantages of the apparatus.

Mr. T. H. WORDSWORTH said that, if the winding-ropes were properly adjusted, there was no trouble with them.

The motion was cordially adopted.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
APRIL 13TH, 1907.

MR. J. H. MERIVALE, PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting and reported the proceedings of the Council at their meetings on March 22nd and that day.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. THOMAS ARNOLD, Civil and Mining Engineer, Castle Buildings, Llanelly.

Mr. SIMPSON CROMBIE, Colliery Manager, Banks House, Durham.

Mr. ALLAN ARTHUR DAVIDSON, Mining Engineer, c o Mr. F. F. Fuller, 138, Salisbury House, London, E.C.

Mr. WILLIAM DICK, Consulting Engineer, 190, Palmerston House, Old Broad Street, London, E.C.

Mr. LIONEL ASHER JACOBS, Colliery Manager, E. I. R. Collieries, Giridih, Bengal, India.

Mr. EVAN JONES, Quarry Manager, Bryn Golen, Station Road, Festiniog, Blaenau Festiniog.

Mr. HENRY STUART MARTIN, Mining Engineer, Trewern, Dowlais.

Mr. LEBERECHT FERDINAND RICHARD SCHNABEL, Consulting Mechanical Engineer, Salisbury Buildings, 443, Bourke Street, Melbourne, Victoria, Australia.

Mr. DANIEL SNEDDON, Colliery Manager, 73, Scott Street, Newcastle, New South Wales, Australia.

Mr. NEIL TAYLOR, Mechanical Engineer, 58, Frederick Street, Loughborough.

Mr. ISAAC WILLIAMS, Mining and Quarrying Engineer, Elterwater, Ambleside.

Mr. ROBERT WOOD, Colliery Manager, 8, Olympia Gardens, Morpeth.

ASSOCIATE MEMBER—

Mr. HANS VON LOEWENSTEIN ZU LOEWENSTEIN, Friedrichstrasse, 2, Essen-Ruhr, Germany.

ASSOCIATES—

Mr. THOMAS BATES, Under-manager, West Wylam Terrace, Prudhoe, Ovingham, S.O., Northumberland.

Mr. CHRISTOPHER ROBINSON, Back-overman, Dudley Colliery, Dudley, S.O., Northumberland.

Mr. ROBERT WARDLE, Under-manager, Edgewell Terrace, Prudhoe, Ovingham, S.O., Northumberland.

Mr. FOSTER WILLIAMS, Assistant Mine- and Quarry-manager, Rothay Cottage, Grasmere, S.O., Westmorland.

Mr. GEORGE WOOD, Back-overman, Dudley Colliery, Dudley, S.O., Northumberland.

STUDENTS—

Mr. ERNEST HODGSON KIRKUP, Mining Student, Peases West Collieries, Crook, S.O., County Durham.

Mr. THOMAS EDWARD SLATER, Mining Student, Blaydon Burn Colliery, Blaydon-upon-Tyne, S.O., County Durham.

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RAND MINES, LIMITED, The Corner House, Johannesburg, Transvaal.

DISCUSSION OF MR. W. E. GARFORTH'S PAPER ON "A NEW APPARATUS FOR RESCUE-WORK IN MINES."*

Mr. W. C. BLACKETT said that, from what he had seen of rescue-work at collieries, he thought that the so-called rescue-appliances would seldom come into use. He could not remember a single instance in which he would have felt safer if he had been provided with such an apparatus, or any instance where he thought a single life could have been recovered by such means. He was, however, bound to say that instances could arise, but it would be very seldom indeed; and, if they did arise so very seldom, then he was afraid that, in the course of years, the use of the apparatus would not be sufficiently practised or persisted in. Therefore from that very fact, when called upon, it would very likely constitute a source of danger. It did not seem to him that such apparatus should be lightly used. He would not like to go into any mine, for the purpose of exploration after an explosion, with the intention of putting on

* *Trans. Inst. M. E.*, 1906, vol. xxxi., page 625.

a headgear, unless he was certain that life was to be saved only in this way; and he thought that was the attitude that should be assumed. The use of such apparatus merely for the sake of re-establishing ventilation would risk a valuable life, if anything went wrong while the wearer was out of immediate reach, amid irrespirable gases. If it were known that a person was in a known place and could be reached in a certain time, under those circumstances an apparatus of this kind would be extremely useful; but the difficulty he foresaw was that men would get out of practice in its use, and he thought that if they were to establish anything in the nature of rescue-stations and appliances (as he hoped they would), they must be extremely careful that the means they used were such that they would be constantly kept in practice, and with a sort of discipline, which he feared they were not likely to get at collieries.

The PRESIDENT (Mr. J. H. Merivale) said that, at the invitation of Mr. W. E. Garforth, he and some other members of the Institute had visited the rescue-station at Altofts collieries, and he was favourably impressed with it; but he came to the conclusion that persons must be specially trained in the use of rescue-appliances. Mr. Blackett had pointed out that he would not like to use the apparatus unless there was some strong reason; but he would go further than Mr. Blackett, and would not put it on, under any circumstances, until he had had previous practical training in its use. Mr. Garforth was of opinion that there should be a rescue-station in each district; for instance, in Newcastle-upon-Tyne for Durham and Northumberland. A number of men should be trained, and each man should have his own apparatus that would fit him in the same way as his clothes did. Such men, so fitted and trained, would be, humanly speaking, absolutely safe in irrespirable gases, and could do hard work for two or three hours. These appliances were liable to get out of order; but if they were stored in a central rescue-station in Newcastle-upon-Tyne, under a trained man, they could be kept in order ready for use when necessary. He hoped that colliery-owners in their district might do something towards carrying out such an arrangement.

Mr. W. C. BLACKETT said that he was not prepared to agree that even men who were practised in the use of rescue-appliances

could put them on their heads and shoulders and be perfectly and absolutely safe. It struck him very forcibly, in reading the account of the recovery of the Courrières collieries, that not a single life was saved by the use of the apparatus and equally strongly that one life was lost. An unfortunate man, who was wearing the apparatus, was killed, and the helmet, torn off his head, was found lying by his side. This result showed that it was not to be accepted without reserve that men were perfectly safe when using such appliances. If rescue-appliances must be provided, he was prepared to suggest how that could be effected for Durham and Northumberland. It was very probable, even if men were specially trained, that untrained persons would be required to put on the apparatus: if a body of trained men went to a colliery after an explosion, they could not be turned loose in the pit without somebody to guide them, and that might be a person familiar with the workings, who might not have had any experience of rescue-appliances.

Mr. Henry Lawrence said that if it were granted that they could find an apparatus which answered all purposes for saving life without the present encumbrances, it was a very poor argument to advance that, after a time, the apparatus would get out of date, or would not be kept in proper order for work.

Mr. T. E. Forster said that he had an open mind on the matter, but until somebody showed that there was more necessity for the use of such appliances than was evident at present, he did not think that it would be desirable to provide them. He had been connected with the mines of Northumberland for many years, and could not recollect a case where such appliances were required, except at Killingworth colliery, where the Fleuss apparatus was used. The difficulty there was not, however, in getting out those who were unprovided with the apparatus, but in rescuing the man who was wearing it.

The President (Mr. J. H. Merivale) remarked that the man who was killed at the Courrières collieries was not accustomed to the use of the appliance.

DISCUSSION ON THE EXPLOSION AT WINGATE GRANGE COLLIERY.*

Mr. DONALD M. D. STUART (Bristol) wrote that the *Reports* presented a lucid description of the explosion, with perfect agreement as to its origin; and contained valuable evidence for discussing the causes of the disaster. The explosion evidently originated in coal-dust in the main intake-airway where over 26,000 cubic feet of air was passing per minute, and where gas could have no existence. Explosions of gas had been so exhaustively investigated that the conditions were known, and remedies were available in ventilation and safety-lamps that made such explosions preventible; but the dangers of coal-dust were not so well known. It was true that evidence had been accumulating for several years showing that the coal-dust deposited in mines was capable of originating and propagating explosion; but where there had been long experience of immunity from explosion in circumstances supposed to be favourable to coal-dust ignitions, it was still difficult for many to realize that explosion could be caused by coal-dust alone. Wingate Grange colliery, for example, had been worked for over 40 years without any explosion or ignition of coal-dust; and in recent years changes had been made in the ventilation and explosives, that were supposed to enhance its safety: consequently no apprehension existed that there was danger in the coal-dust. The danger now stood disclosed by the explosion, and on evidence of fact so complete that, supplemented as it was by the records of similar disasters, the mining world might be fairly asked to accept the fact that coal-dust was an explosive agent.

Many interesting questions arose, and amongst them the enquiry whether the coal-dust possessed explosive properties during the 40 years of immunity from explosion, or whether they were of recent development; it might be useful to consider the circumstances that were reported. The effect of air-currents sweeping through haulage-roads had been often observed, and here the moisture must have been largely absorbed in a period of 40 years; but in some mines both deposition of coal-dust and with-

* *Reports to His Majesty's Secretary of State for the Home Department on the Circumstances attending an Explosion which occurred at Wingate Grange Colliery, Wingate, on the 14th October, 1906*, by Mr. A. H. Ruegg, K.C., and Messrs. R. D. Bain and J. B. Atkinson, M.Sc., two of H.M. Inspectors of Mines, 1907 [Cd. 3379].

drawal of moisture were gradual, and might extend over many years before the danger-stage was reached. It also appeared that up to a recent year the mine was adequately ventilated by a fan producing 102,000 cubic feet of air per minute;* but subsequently the new fan had yielded nearly twice the quantity, namely, 193,478 cubic feet.† If this increased quantity of air was taken through the original intake-airways, the velocity of the currents must have been considerably raised, accelerating the absorption of moisture, increasing leakage from the tubs, and adding to the coal-dust deposits in the haulage-roads. One effect of the increased ventilation would therefore be dry intake-airways and a more abundant supply of coal-dust; another, the increased sensitiveness of coal-dust after exposure to air-currents, which had been observed by Prof. P. P. Bedson. These circumstances suggested that the explosive properties of the coal-dust might have been of recent development, and this was consistent with the fact that the explosion occurred after the changes in the ventilation.

He (Mr. Stuart) had found similar circumstances in his investigations of the explosions at the Camerton and Timsbury collieries. Both mines had been worked with immunity from explosion for from 70 to 100 years; but the ventilation was largely increased with no alteration in the dimensions of the intake-airways, whereupon explosive properties developed in the coal-dust distributed in the haulage-roads, and extensive explosions occurred.

The ventilation of mines had claimed principal attention in past legislation, with limitation of view to dilution and removal of gas; but the time had now come when another factor of even more disastrous energy had to be considered, since it was evident that while large quantities of air, necessarily travelling at high velocity, would dilute and render harmless noxious gases with a large margin of safety, they at the same time developed a more serious danger in creating explosive conditions throughout the main arteries of the mine, that needed only kindling at one point, to traverse the whole.

* *Reports to His Majesty's Secretary of State for the Home Department on the Circumstances attending an Explosion which occurred at Wingate Grange Colliery, Wingate, on the 14th October, 1906*, by Mr. A. H. Ruegg, K.C., and Messrs. R. D. Bain and J. B. Atkinson, M.Sc., two of H.M. Inspectors of Mines, 1907 [Cd. 3379], page 16.

† *Ibid.*, page 17.

Considerable labour had been spent for many years in the almost hopeless mission of obtaining explosives that would not ignite gas or coal-dust in mines; the subjects of dust-tight tubs and watering haulage-roads were now receiving much attention, but the potent relations of air-currents to the coal-dust question, appeared to have been overlooked. With air-currents at velocities of 400 to 800 feet per minute, and loaded tubs travelling in the opposite direction at equal speeds, depositions of coal-dust along the arteries of the mine, and development of explosive properties in the dust, appeared to be almost unavoidable; and he (Mr. Stuart) suggested that regulation of the ventilation to remove noxious gases with least effect in creating dangerous coal-dust, claimed serious attention.

The disaster threw further light on the behaviour of explosives when used in practical conditions; it was well known that detonating permitted explosives had failed to ignite coal-dust in the large number of tests and experiments made in this country, and the permitted explosives were supposed to possess a high degree of safety; it was recorded here that "a permitted explosive was only used as an extra precaution";* but this explosive unfortunately caused an explosion with coal-dust, although such an event had not happened with all the previous shot-firing. It was true that the explosive was not used as required by law; but it was used by a competent shot-firer, who had evidently been misled by the reports that detonating explosives could not ignite coal-dust. It was also true that the explosive should have been used in a properly drilled hole; but the same class of explosive was used in holes at Albion colliery, and ignited the coal-dust with an awful result. The doctrine was still taught that a detonating explosive was the safer, because its products expanded with lightning-like rapidity, and consequently cooled down before they could ignite gas or coal-dust. This theory was answered by the Wingate Grange explosion with its fatal record.

There were several very interesting observations on the propagation of the explosion. The men killed by violence were at

* *Reports to His Majesty's Secretary of State for the Home Department on the Circumstances attending an Explosion which occurred at Wingate Grange Colliery, Wingate, on the 14th October, 1906*, by Mr. A. H. Ruegg, K.C., and Messrs. R. D. Bain and J. B. Atkinson, M.Sc., two of H.M. Inspectors of Mines, 1907 [Cd. 3379], page 18.

places distant from each other, and it was not quite clear whether the authors suggested that the violence was due to a force rushing through the field of explosion, or to the sudden development of force where the men stood. It would be very useful if further information could be given on this point, and bearing upon the development of violent action also at the top of the drop staple. It was recorded that there were indications of force " between the shafts and the stable-way junction and in-bye of the junction; then, extending about 270 feet, there was a distinct length of road on which, although there were things to disturb, no disturbance had taken place; beyond the undisturbed length evidences of a renewal of disturbance were apparent."* It would be useful to know the actual position of this space of repose: the stable-way junction was marked at 720 feet from the shaft, and the shot 1,308 feet beyond the junction; while the shot-firer was found some 42 feet from the shot, bearing marks of violent forces. It was also shown that propagation failed a short distance beyond the stable way, and at 2,700 feet from the junction, in the north-east way; at the latter point abundant deposits of coked dust were observed, presumably, therefore, the propagation did not fail for want of coal-dust. It would promote the discussion of this subject if further light could be thrown on the places of failure of propagation, and the causes.

The action of Edward Murton (master shifter) and William Peat (examiner) deserved to be chronicled; and, if what they did could be embodied in " Pit Stories," for circulation amongst miners generally, such intelligence, self-reliance and courage would have far-reaching effects in keeping that standard to the front, and must have an educational value in the accidents of mining.

He (Mr. Stuart) would like to join with the members in an appreciation of this valuable contribution by the authors on the subject of colliery explosions.

Mr. Philip Kirkup (Birtley) wrote that the evidence was unanimous in proving that fire-damp did not enter into the cause, no gas ever having been reported and the point of origin

* *Reports to His Majesty's Secretary of State for the Home Department on the Circumstances attending an Explosion which occurred at Wingate Grange Colliery, Wingate, on the 14th October, 1906*, by Mr. A. H. Ruegg, K.C., and Messrs. R. D. Bain and J. B. Atkinson, M.Sc., two of H.M. Inspectors of Mines, 1907 [Cd. 3379], page 24.

being one that was very unlikely to harbour any. The evidence was also very strong, to prove that the explosion was caused entirely by an ignition of coal-dust and air, and originated from flame due to a charge of geloxite being fired on a projecting ledge of rock, probably covered by a mixture of grease and coal-dust. The roadways were described as not particularly dusty, proving that it was the very finest particles of dust that were dangerous—those which were most likely to be unobserved, such as would rest on the top of baulks and props, etc. It did not therefore appear that brushing the sides, roof, etc., would be advantageous, unless effective watering was carried on at the same time, to prevent the finer particles, thus disturbed, from being carried inbye by the air-current. Further, by removing the dust by brushing, the heavier portions, which are not dangerous, are removed, and the lighter and inflammable particles, which are too light to fall to the ground, are left. Consequently, in order to effectively deal with the dust, it should be brushed and cleared away at the same time as a water-spraying tub is working backward and forward on the inbye side; and also further assisted by fixed sprays at different parts of the roadway, fed by water from the rising main of the pumps. These appliances should produce a spray of such fineness that it would saturate the atmosphere, the moisture being carried by this means into every corner and also to the face of the workings. This water-spraying should be worked during all hours of the day, and it would also moisten dust carried in by the intake-air from the screens as well as that made from the full tubs.

The following lessons may be learnt from this explosion:—(1) The removal of coal-dust from the roadways, assisted by tub-sprays and sprays under pressure from the rising main of the pumps. (2) The thorough examination, by questions, of all shot-lighters as to their duties and the rules to be enforced, when giving out licenses. (3) The instilling of the fact into shot-lighters that, even with a permitted explosive, no shot should be fired where gas is present; and that, when using such an explosive in an unstemmed shot-hole, or where it has little work to do, it is possible to ignite coal-dust without the presence of gas. (4) Under no consideration must any charge of explosive be fired, except in a properly drilled hole, efficiently stemmed with clay. And (5) the absolute prohibition of blasting on main haulage-roads without a written authority from the manager.

Mr. C. C. LEACH (Seghill) wrote that Mr. Ruegg stated that all main roads should, as far as practicable, be kept free from coal-dust. He (Mr. Leach) thought that the act of brushing the roadways with hand-brushes would raise a cloud of impalpable dust, and therefore of the most inflammable character, which would settle on the sides and roofs. This fine dust would be a greater source of danger than dust containing gritty and larger particles of coal and shale, which would tend to prevent the ignition of the dust; the gritty and larger particles forming the inert portion of it. It might, indeed, be desirable to introduce shale-dust to neutralize the coal-dust. In very hot pits, extensive watering would make it almost impossible to work in the steamy atmosphere, which would prove injurious to the health of the workmen.

Mr. J. P. KIRKUP said that Mr. R. L. Galloway* appeared to question the verdict or decision of H.M. inspectors of mines and Mr. Ruegg as to the cause and origin of the Wingate explosion. He thought that mining engineers in the county of Durham, however, were generally in agreement with the report of H.M. inspectors of mines; and, had those gentlemen been present, he would have liked them to have refuted, what he might call presumptuous assertions founded, not on personal observation and knowledge, but entirely on a superficial consideration of the evidence given by the witnesses.

Mr. W. C. BLACKETT said that he was not surprised that explosions occurred, arising, like that at Wingate Grange colliery, out of the use of high explosives, when for so many years there had been no serious explosions from gunpowder. It was a fact that men would use high explosives under conditions where they would never have dreamt of using gunpowder, and that was the case at Wingate Grange colliery. It was futile for Mr. R. L. Galloway, or anyone else, to controvert the observations that were made at Wingate Grange colliery, as it was absolutely certain that the conclusions of H.M. inspectors of mines as to the cause of the explosion were correct. There could be no doubt that the explosion was caused by the particular shot fired under the circumstances described in the report. The man who fired the shot would never have dreamt of doing what he did if he had been

* "The Wingate Grange Explosion," by Mr. R. L. Galloway, *The Colliery Guardian*, 1907, vol. xciii., page 635.

required to use gunpowder; and therefore they had a curious anomaly, that in this case gunpowder would have been the safer. No man would place a charge of gunpowder on the top of a projecting stone, and cover it with grease and dust. The man knew that an explosive, like geloxite, containing nitro-glycerine, would break down a piece of stone, and, having nothing else particular to do, he put his time in that way. There could be no doubt about the origin of the explosion.

After reading the reports on the Wingate Grange explosion, the uppermost thought in his (Mr. Blackett's) mind was the length of time wasted at the enquiry before the coroner, some of which was due to the necessity of imparting technical instruction to persons who took prominent parts therein and who were ignorant of even the elements of mining. The report of Mr. Ruegg, considering his lack of familiarity with mining, was most able; and there were few men who, under similar circumstances, could have written so clearly on the subject. What he might say, therefore, was not in disrespect to that gentleman, but was meant to find fault with a system which permitted a person, more or less completely ignorant of mining, to report in authoritative terms, and to pass opinions upon so highly technical a subject. The reports were, he supposed, intended to be records for future guidance, and as such should only be written by men who knew the subject completely; otherwise they would tend to mislead (as he thought that this one might do, and as others possibly had done), notably that written by Mr. J. E. Joel on the Brancepeth explosion.* He (Mr. Blackett) would therefore warn students against the conclusions drawn by gentlemen who came down as official reporters to the Home Secretary, and he advised them to stick to the facts related so clearly and ably by the men who knew, namely, H.M. inspectors of mines. In this case, an eminent lawyer, who might never have been inside a mine in his life, ventured to make a report on the cause of an explosion in a mine and on the means which, in his opinion, should be adopted to guard against like occurrences. He (Mr. Blackett) valued the opinion of a lawyer on law, but on mining he regarded it as merely interesting.

* *Reports to the Right Honourable the Secretary of State for the Home Department on the Circumstances attending an Explosion which occurred at the Brancepeth Colliery in the County of Durham, on the 13th of April, 1896*, by Mr. J. Edmondson Joel, Barrister-at-law, and by Mr. R. Donald Bain, H.M. Inspector of Mines, 1896 [C.-8174], pages 3 to 14.

It was instructive to hear from Mr. Ruegg's report that he was of opinion that the ventilation was sufficient, that part of the haulage-road was dusty and that the dust was dry, but this would perhaps be more correctly described as the balance of opinion of those who knew. It was also interesting to observe how reluctantly Mr. Ruegg accepted what he called the "theory," put forward by the officials of the mine with the help of expert assistance; but it was more than theory, it was a definite fact ascertained by those who knew, and scepticism was not warranted.

He (Mr. Blackett) chiefly objected to Mr. Ruegg's opinion that the system adopted by Mr. C. S. Carnes, at his collieries, of brushing down the dust with hand-brushes, if it were adopted generally, would greatly minimize the risk of explosion by coal-dust. Personally, he considered that brushing down dust was not only quite impracticable, but was more or less futile, and perhaps even somewhat dangerous. No doubt large quantities of small particles of matter might be removed in this way; but he maintained that it would be impossible to brush off from timber and other ledges so much dust as would leave a quantity so small as to be harmless, and it was dangerous to give an impression that such brushing could be effectual. Moreover, the most dangerous dust would be moved on by this means nearer and nearer to the face, carried by the air-current to a part of the mine where it would be even more objectionable than before.

If managers would only make up their minds to use water, and with a fine impalable spray wash the dust from the timber and ledges, the dust would then be effectually removed or rendered harmless for a considerable period. Water could reach places, untouched by the brush, and could be used in quantities which would have but a superficial effect, without the necessity of swilling. It was quite true that some stones would not stand water, but there were few that would not bear a superficial quantity. He thought that this danger (although freely admitting that it existed) had been made far too much of, and he was afraid that the exaggeration, in the end, would do more harm than good.

Mr. T. E. Forster said that he did not quite see himself why a lawyer should make a report on collieries; but, if the members read Mr. Ruegg's report, they would find that the opinions which he expressed were really those of H.M. inspectors of mines. He (Mr. Forster) could not understand why they were

not allowed to report alone. In this instance, Mr. Ruegg seemed to have accepted their opinions and put them forward as his own; but, on another occasion, the gentleman instructed by the Home Secretary might differ with H.M. inspectors of mines, and he might make recommendations at variance with theirs and with the general practice. The Royal Commission on Accidents in Mines, now sitting, had paid great attention to the dust-problem. The evidence was published week by week as the sittings proceeded, and was scarcely necessary to call the special attention of mining engineers to the difficulties and dangers in connection with coal-dust, for they had all been aware of them for many years. The publication of the evidence, however, would be very helpful, in so far as it would draw the attention of under-officials and shot-firers to the matter; for one knew from personal experience that these men did not read professional papers, and were not fully aware of the necessity of counteracting these dangers. He approved of the suggestion that they should be cross-examined by colliery managers from time to time. When Special Rules were established, and for some time afterwards, everybody observed them; but after a few years they were apt to be forgotten, and it was desirable that everyone's ideas should be furbished up occasionally. He thought that it would prove advantageous if copies of the reports upon the Wingate Grange explosion were distributed to managers and under-managers for careful consideration.

Mr. S. Hare, while he agreed with Mr. Blackett in almost every way in connection with the use of water, said that watering could not be adopted under all conditions, and then the only thing that could be done was to adopt brushing. For instance, watering was extensively adopted at the Murton collieries, and several miles of water-pipes, from 1 inch to 1½ inches in diameter, had been laid, with hydrants fitted at distances varying from 150 to 250 feet apart. He was a believer in the use of water-sprays and occasionally used them. Any system of watering was, however, in his opinion of little value unless the dust was gathered together and sent out of the pit at short intervals. Brushes were used to a limited extent at the Murton collieries, but only where it was considered unsafe to apply a large quantity of water. He had adopted a system, in connection with the shot-firers, which was, he thought, worthy of emulation. In each district,

where shot-firing was allowed, printed instructions were posted for the guidance of the shot-firers and to ensure that their work should be carried out with the utmost safety. He thought that the posting of these instructions, which were of a stringent character, brought the subject very closely under their notice. In addition, the more important regulations were printed on the back of the license given to each shot-firer, and this helped to impress upon each shot-firer the necessity and the importance of the regulations that he was required to observe.

Mr. C. A. Crofton (Morpeth) said that the masterly report of H.M. inspectors of mines had convinced him that the Wingate Grange disaster was purely and simply a coal-dust explosion. He agreed with Mr. W. C. Blackett and Mr. S. Hare with regard to the watering of haulage-roads, which, although suitable in one pit, might not be so advantageous in another, on account of the nature of the strata and the depth of the pit. Coal varied considerably in its properties, moisture, etc., and tests might prove that all coal-dust would not explode, some being more highly sensitive to ignition than others. Consequently he suggested that coal-dusts from Wingate Grange and from some shallower pits might be tested. In the transportation of coal the larger pieces worked to the bottom of the tub and the dust to the top, and on meeting the intake-air the dust was blown out of the tub and deposited on the sides, timbers, roof, etc. He suggested, as a remedy, that all tubs should be fitted with a lid or cover, which would be removed from an empty tub and put by the landing-lad on a full tub, and then again would be taken off by the shaft-lad and placed in an empty tub. Catches would be fitted on the tubs to prevent the lids from being blown off the tubs. He thought that this method might prevent the formation of 80 per cent. of the dust at present being deposited.

Mr. James Ashworth (Old Colwyn) wrote that it would interest him, and doubtless many other engineers, to have additional information as to the part played by steam. It was stated that the steam-pipes were broken; that the steam from three ranges of pipes was added to the after-damp; and that one survivor, J. McDougall, who escaped alive, was scalded by steam in the Main coal-seam, whilst his mate, J. G. Dixon, was killed by force: was this force from the steam or from the explosion? It might be concluded, after reading the reports, that the flame

of the explosion went down the stable way and burned G. Bloomfield, but not the horse found dead near to him. He (Mr. Ashworth) would, therefore, like to know whether the appearance of Bloomfield might not be due to scalding, and not to burning; more particularly because the horse was not singed, neither were any of the horses singed in the stable. But it was quite conceivable that steam and after-damp were either jointly or severally the cause of their deaths. At Elemore colliery, an explosion, originating in a similar way, was carried down the shafts to the mines below; and therefore, if the dust from the screens made the Low Main haulage-ways dangerous, the shafts themselves must have been still more dangerous, as a consequence of the larger volume of air passing down to the lower mines. In his (Mr. Ashworth's) opinion, the steam saved the lower mines; as no form of water, excepting steam, could saturate an air-current sufficiently to place a barrier in front of a gas or dust explosion. Roughly estimated, air would have to contain over 5 per cent. of water-vapour, or, say, 26 grains per cubic foot, before it could exercise any controlling influence.* Not only did the steam, in this way, serve a most useful purpose as a life-saving agent, but it also appeared to have brought the explosion to a conclusion, before it extended into the second east way, by its effect on the ventilation. Thus, the large volume of steam struggling to escape in every direction, particularly downwards, and acting in like manner as the steam-jet of an injector, might for the time have reversed the ventilation in the Low Main coal-seam: that was to say, both the intake- and return-airways were brought under an influence tending to draw back the intake-air, and to force the return-air down the Harvey staple. The next phase would be during the period of condensation, when air struggling to enter from every direction to fill the void, tended to draw back the advancing flame, supposing that the effect of the steam in the shaft had not already caused the arrestment of the advancing flame by the large volume of dust disturbed. It was a most marked feature in this explosion that the explorers experienced very little trouble from after-damp; and that the men escaping from the second east district also met very little after-damp, or they could not have travelled such long distances before succumbing. He (Mr. Ashworth) regretted that the plans attached to the *Reports* did not

* "The Rate of Explosions in Gases," by Prof. H. B. Dixon, *Trans. Inst. M. E.*, 1892, vol. iii., page 317.

indicate the doors, stoppings, and air-crossings that had been blown out, and consequently where, in addition to the blown-out casing in the upcast-shaft, the air short-circuited after the explosion. For the foregoing reasons, he (Mr. Ashworth) had concluded that excess of dust had brought the flame to an end, and not want of dust, particularly as the greatest heat-effects were demonstrated close to the point where the explosion appears to have terminated; and moreover some at least of the great force exhibited between the shafts and the stable way, must have been due to the escaping steam. He was also of opinion that, had it been possible for the first band of explorers to descend to the Low Main seam sooner than they did, and check the escape of air into the upcast-shaft, most of the men in the north-east way would have escaped alive.

The hygrometrical observations* were interesting, as they showed that the intake-air at the shafts was saturated with water; and, although there was a difference of 1·2 grains between the observations made on October 22nd and those made on November 9th, 1906, yet when the air reached the curve of the second east way, the water-content had risen to 6·2 grains per cubic foot, being on the first date 0·4 grain, and on the latter date 0·2 grain only, below absolute saturation. Therefore, it was doubtful whether it was correct to call either the dust or the atmosphere "dry." At the place where Bloomfield was found, the air was saturated, and carried 6·3 grains of water per cubic foot of air. It was perfectly clear that air saturated with moisture was no protection against the extension of an explosion. On the other hand, it assisted in the oxidation process; and, moreover, in addition, the explosion was reported to have passed over two wet places, of considerable length, although neither of these were indicated on the plans accompanying the *Reports*. With these facts so plainly demonstrated, it was a misnomer to describe the part of the mine traversed by the explosion as "dry."

The analyses of dust were another interesting feature of the *Reports*, but they did not throw any distinct light on the question, as to whether dust containing a certain proportion of ash was explosive or not.† For instance, the dust near Maddison's shot

* *Reports to His Majesty's Secretary of State for the Home Department on the Circumstances attending an Explosion which occurred at Wingate Grange Colliery, Wingate, on the 14th October, 1906*, by Mr. A. H. Ruegg, K.C., and Messrs. R. D. Bain and J. B. Atkinson, M.Sc., two of H.M. Inspectors of Mines, 1907 [Cd. 3379], page 30.

† *Ibid.*, page 35.

contained 44·13 per cent. of ash; and at the point near the end of the explosion on the stable way, 34·80, 39·20 and 44·14 per cent., and in the north district, near the end of the explosion, only 26·95 per cent. These values, when compared with those obtained at Camerton, Courrières and other collieries, did not demonstrate that such percentages of ash were a safe factor. The addition of an analysis of the coal of the different seams would have been useful for purposes of comparison.

Possibly no disaster would have resulted from the shot, if Maddison had not used greasy dust from the roadway to cover the charge, and it was in all probability the great flame from this, as at Timsbury colliery, that really originated the disaster.

Mr. A. M. HEDLEY (Blaydon Burn) wrote that, during the discussion on the *Reports* dealing with the Wingate Grange colliery explosion, Mr. C. C. Leach raised objection to brushing the main roadways as it "would raise a cloud of impalpable dust, and therefore of the most inflammable character, which would settle on the sides and roofs."* Views differed considerably as to the necessity for, or practicability of, keeping all main roads entirely clear of dust throughout their full length; but, in his (Mr. Hedley's) opinion, every dry and dusty colliery should have its roadways dealt with as far as possible in this direction, and he thought that the idea was sound of having, at any rate, certain lengths of the road kept at intervals clear of dust. Surely few engineers would contend that there was no necessity for removing the dust which accumulated in the main roadways, and to his mind the only point in doubt appeared to be the means to be adopted for its removal. Mr. W. C. Blackett was of opinion that "brushing down" was "impracticable" . . . . "and perhaps even somewhat dangerous."† Mr. Blackett favoured, however, the system of watering, for the purpose of washing off the light dust which had accumulated on the roof and sides; and a similar expression of opinion from Mr. Hare, with the latter's extensive experience at Murton, should carry considerable weight.

An effective combination, if feasible, of brushing and watering seemed desirable, and he (Mr. Hedley) wished to recommend a means of accomplishing this object which had recently been suggested to him by Mr. R. Crombie, an associate of the Institute. It was an idea which the latter had previously carried

* *Trans. Inst. M.E.*, 1907, vol. xxxiii., page 188. † *Ibid.*, page 190.

out, and he (Mr. Hedley) had since tried it with satisfactory results. He would assume that a length of 300 feet was required to be cleared of dust on a main haulage-road, which at the same time served as an intake-airway. On the inbye side (or the outbye side, if a return-airway) of this area to be treated, a piece of brattice-cloth, thoroughly soaked in water, was attached along its upper edge to the roof-timber, across the full width of the road. It was hung at such a distance from the roof as was deemed necessary, without offering too great an obstruction to the ventilating current; and, in the case of a strong current of air, the canvas should be weighted by attaching pieces of timber to its lower edge. When the brattice-cloth was fixed, the dust-zone was treated by water-sprays to such an extent as the nature of the seam's roof or thill would allow, and it was then found that the operation of brushing the dust from the roof and sides could be carried out with impunity. The light dust raised, if carried forward by the air-current, would, on meeting the wet canvas-obstruction, be moistened and fall in layers on to the floor, whence, with the bottom dirt, it could be removed and filled into a tub when the operation was completed. Possibly a succession of wet sheets might even give better results, and wet canvas stretched along the roof and sides would further improve matters. It was possible that one sheet, treated with a continuous spray of water throughout the brushing operation, would answer the required purpose. It appeared to him (Mr. Hedley) that the efficacy of this treatment in the final capture of the fine dust depended on the fact that the dust was driven against a wet surface, instead of the water being thrown on to the dust and so acting as an agitating and disturbing agent.

The PRESIDENT (Mr. J. H. Merivale) said that the chief point brought out by the reports on the Wingate Grange explosion was the danger from coal-dust. It seemed a truism that there was danger connected with coal-dust, but on reading the *Reports* it appeared that many persons still are, or at any rate were, in doubt as to the dangers connected with it. He agreed with Mr. W. C. Blackett to some extent as to the undesirability of bringing down gentlemen ignorant of mining matters to report on colliery explosions. Perhaps the classical instance was that of Haswell colliery in 1844, when Sir Charles Lyell and Prof.

Michael Faraday, two of the most eminent men of the day, advised mining engineers to put in pipes to drain gases from the goaves. If, however, an able man, who had no prejudices and knew nothing about mining, presided at an enquiry and heard all that was said on both sides, he was in a good position to form an opinion.

DISCUSSION OF MR. E. SEYMOUR WOOD'S PAPER ON "SINKING THROUGH MAGNESIAN LIMESTONE AND YELLOW SAND BY THE FREEZING-PROCESS AT DAWDON COLLIERY, NEAR SEAHAM HARBOUR, COUNTY DURHAM."*

Mr. James H. Brace (New York) wrote that, while this work was entirely successful, it appeared (1) to emphasize the necessity of keeping the borings plumb and at a uniform distance; and that (2) it was very difficult to form an ice-wall while water was running through the material to be frozen, and that every precaution should be taken to stop any such flow before starting freezing. He understood that the contractors for the work described had had wide experience of this kind of work, and he would like to enquire what experiments had been made with lower temperatures. With the machinery now in use, it was practicable to reduce the temperature of the brine down to −30° Fahr., and it would seem to be advantageous to make it as low as practicable. In conclusion, there had, so far as he knew, been only two applications of the freezing process for excavation in America in recent years. One of these was on the rapid-transit tunnel between New York and Brooklyn. This had recently been fully described in the technical press;† and the other work had not as yet reached a final stage.

Mr. M. Malplat's paper on "Sliding-trough Conveyors" was read as follows:—

* *Trans. Inst. M. E.*, 1906, vol. xxxii., page 551.

† "The Freezing Process in the Battery Tunnel, New York," *The Engineering Record* [New York], 1906, vol. liv., page 656.

SLIDING-TROUGH CONVEYORS.*

By M. MALPLAT.

At the present time, in No. 7 pit of the Lens collieries, the Saint-Augustin seam is being worked, with the following characteristics:—The seam is formed of one single bed of coal, varying from 20 to 24 inches (0·5 to 0·6 metre) thick in the more regular portions. The coal is hard, but it generally cleaves into big blocks, without bedding. The roof is bad, and the floor variable. The average dip is 11 degrees.

The method originally adopted for working this seam was by means of rising gateways, 52 feet (16 metres) wide, with a road in the middle of each. The working-cost of this system was somewhat high, as the essential elements, namely, the hewing of the coal and the opening of the roads, were expensive. The stone taken up in the roads must be thick, because the seam is thin; and, in addition, each foot of roadway corresponds only to a small output of coal. In order to reduce the costs of stone-work, the management were induced to suppress every alternate road, giving each working-face a length of 100 feet (30 metres). It then became indispensable to establish, on either side of the face, which measured 50 feet (15 metres), some method of conveying the coals.

The following system was adopted:—The coal-face, at each side of the rising gateway, is made at a small angle with the strike of the seam, and with a slight slope towards the road; and, in the space between the coal-face and the goaf, rails weighing 10 pounds per yard (5 kilogrammes per metre) have been laid (Fig. 1). The gauge of the rails is 9½ inches (24 centimetres); they are connected by riveted sleepers, and form lengths of 8¼ feet (2½ metres), fitted to the neighbouring lengths by means of fish-plates. Along this road slides a trough made

* "L'Emploi . . . . de Couloirs glissants pour le Boutage dans les Tailles," by Mr. M. Malplat, *Comptes rendus mensuels des Réunions de la Société de l'Industrie Minérale*, 1907, pages 27-28.—Translated by Prof. Henry Louis, M.A.

of sheet-iron, 0·12 inch (3 millimetres) thick, in the form of a semi-cylinder, 20 inches (50 centimetres) in diameter and 6½ feet (2 metres) long. This trough is protected by three rings of half-round iron, which rest upon the rails (Fig. 2). A rope, 50 feet (15 metres) long is attached to each end of the trough, and allows it to be drawn alternately from the further end of either side of the face to the road.

The working is organized as follows:—Five workmen, one of whom is an assistant, are engaged at the face. The assistant works in the roadway, drags the troughs when they are full, and loads the coals into the tubs. The amount of pull required to move the trough is very small, and it is about the same in either direction, full or empty, on account of the gentle slope of the road. Unloading the trough is particularly easy, when, as is the present case, the cut for the roadway is made in the

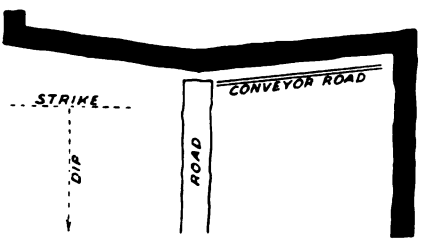

FIG. 1.—PLAN OF GATEWAY.
SCALE, 48 FEET TO 1 INCH.

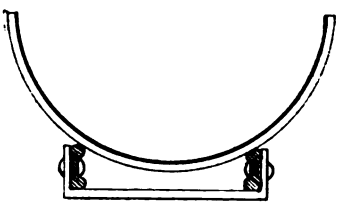

FIG. 2.—SECTION OF CONVEYOR.
SCALE, 12 INCHES TO 1 INCH.

bottom-stone. The trough is tipped into the tub standing in the roadway by attaching the rear cord of the trough to a prop at the far end of the face; and, by suitably regulating the length of this cord, the trough can be abruptly stopped, producing automatic discharge of the contents. In this method of discharge, the trough is open at either end; but often, on the contrary, in order to increase its capacity, the lower end is closed by a movable door. The trough has a capacity of about 3½ cubic feet (2 hectolitres); in practice, three troughs fill a tub carrying 10½ cwts. (545 kilogrammes); and two troughs are sufficient when the seam is thicker, and the trough can be loaded above the level of its edges. Very little height is required, as the trough will pass under a height of 14 inches (0·35 metre).

The system has been well received by the workmen, who found formerly that the transport of the coal was laborious on

account of the thinness of the seam. The coal is loaded, as fast as it is broken down, into the trough, and the face always remains free for the ventilating current and the passage of the miners. The width of the working-face of each gateway has been doubled without increase of the hewing prices, and no payment is made for laying the road for the conveyor. These troughs are also used for throwing back into the goaf the débris made in cutting the roads, part of which was formerly sent to bank in tubs.

Mr. T. C. Futers said that the trough, merely lying on the rails and having a capacity of 3½ cwts., would require a strong boy to move it.

Mr. Henry Lawrence said that the appliance seemed a very unusual one: its adoption might have been necessary under the circumstances in which it was employed, but he thought that friction would soon wear out the trough.

Mr. T. E. Forster asked what strain or pull was required to move the empty and the loaded trough, whether the system had been in use any length of time, and the cost of this method of conveying.

Mr. C. A. Crofton remarked that tubs carrying 10½ cwts. were rather large for a seam less than 2 feet high. The stone-work would consequently be very costly.

The President (Mr. J. H. Merivale) said that the method had evidently been developed, in order to reduce the cost of working thin seams by decreasing the number of gateways. Attempts had been made, some with considerable success, and others with not so much; and one could hardly tell from a cursory glance whether this proposal was likely to prove successful.

Mr. M. Walton Brown read the following "Memoir of the late John Daglish."

MEMOIR OF THE LATE JOHN DAGLISH.

By M. WALTON BROWN.*

The late Mr. John Daglish, mining and civil engineer, of Rothley Crag, Cambo, Northumberland, was born in Newcastle-upon-Tyne, on June 26th, 1828. He attended Dr. John Collingwood Bruce's school in Newcastle-upon-Tyne from 1836 to 1838. Afterwards he went to Wesley College, Sheffield, where he remained until 1843; and during that year he commenced his apprenticeship as a mining engineer with Mr. Nicholas Wood, at Killingworth collieries. In 1848, he went to Urpeth colliery, as assistant viewer to Mr. Edward Fenwick Boyd; and from October 1849 to 1850, he attended lectures at King's and University Colleges, London.

In 1850, he went to Barrington colliery, as viewer, under Mr. James Longridge; and, in 1852, he was appointed viewer of Radcliffe colliery. In October, 1854, he was appointed viewer of Seaton colliery, then the property of the Earl of Durham and the Owners of Hetton collieries.

In 1855, he married Miss Sarah Ellen Robson of Paradise, near Newcastle-upon-Tyne, and of the marriage there was one daughter, Adelaide Mary, who was born at Seaton House on December 28th, 1856, and died at Rothley Crag in 1905.

Mr. Daglish became viewer of the Hetton collieries in 1859. He was in 1863 appointed chief viewer to the collieries belonging to the Marchioness of Londonderry; in 1865, he became general manager; and he resigned this position in 1869.

He became managing director of the Whitburn colliery in 1873; and in the same year, he was appointed managing director of Cwmaman colliery, in South Wales, and held the appointment until his resignation in 1895. He was also agent for Kimblesworth colliery, Durham; Silksworth colliery, Durham; Houghton Main colliery, Yorkshire; Swaithe Main colliery, Yorkshire;

* Extended and revised from the *Newcastle Daily Journal*, August 16th, 1906, page 5.

and Manvers Main colliery, Yorkshire. He was a director of Llest colliery, South Wales; and as check viewer held numerous mining agencies.

In July, 1891, Mr. Daglish resigned all colliery management, and purchased the Rothley Crag estate of 1,100 acres. The building of the hall at Rothley Crag was completed in 1895, and here he chiefly resided until his death.

He was one of the 44 "colliery owners, viewers and others interested in the coal trade," who met in Newcastle-upon-Tyne, on July 3rd, 1852, and founded The North of England Institute of Mining and Mechanical Engineers, "to meet at fixed periods and discuss the means for the ventilation of coal-mines, for the prevention of accidents, and for general purposes connected with the winning and working of collieries." He retained his membership up to his death, and at all times took a keen interest in the furtherance of the objects of the Institute. He was for many years a member of council, and a Vice-president, and occupied the office of President during the years 1884 to 1886. Mr. Daglish, in addition to taking part in the business of the meetings, wrote the following papers:—

"The Relative Heating and Economic Values of Round and Small Coals," *Trans. N. E. Inst.*, 1856, vol. iv., page 283.

"Experiments on the Strength of Wire-ropes and Chains," *ibid.*, 1859, vol. vii., page 211.

"The Injurious Action on Iron in Upcast Shafts," *ibid.*, 1860, vol. viii., page 179.

"The Cause of the Loss of Strength in Iron Wire when Heated," *ibid.*, 1860, vol. viii., page 181.

"The Construction of Ventilating Furnaces," *ibid.*, 1861, vol. ix., page 131.

"The Various Modes of Ascertaining the Velocities of Currents of Air in Mines, in order to Determine the Quantities Circulating in a given Time," in conjunction with Mr. John Job Atkinson, *ibid.*, 1861, vol. x., page 207.

"The Destructive Action of Furnace Gases in Upcast Shafts," *ibid.*, 1861, vol. xi., page 19.

"The Donesthorpe, Firth and Ridley Coal-cutting Machine," in conjunction with Mr. Lindsay Wood, *ibid.*, 1863, vol. xii., page 63.

"The Ventilation of Underground Boilers," in conjunction with Mr. William Armstrong, *ibid.*, 1863, vol. xii., page 79.

"Paradoxes in the Ventilation of Mines," in conjunction with Mr. John Job Atkinson, *ibid.*, 1863, vol. xii., page 93.

"The Magnesian Limestone of Durham," in conjunction with Mr. George Baker Foster, *ibid.*, 1864, vol. xiii., page 205.

"Minerals and Salts found in Coal Pits," in conjunction with Mr. R. Calvert Clapham, *ibid.*, 1864, vol. xiii., page 219.

"Certain Improvements in the Construction of the Water-gauge," *Trans. N. E. Inst.*, 1865, vol. xv., page 103.
"The Broadbent Patent Safety-cage," *ibid.*, 1866, vol. xvi., page 33.
"The Conveyance of Coal Underground," *ibid.*, 1867, vol. xvi., page 53.
"A New Application of the Water-gauge for ascertaining the Pressure of the Ventilating Column in Mines," *ibid.*, 1867, vol. xvii., page 27.
"The Counter-balancing of Winding-engines," *ibid.*, 1871, vol. xx., page 205.
"Some Remarks on the Beds of Ironstone occurring in Lincolnshire," in conjunction with Mr. R. Howse, *ibid.*, 1874, vol. xxiv., page 23.
"The Application of Counter-balancing and Expansion to Winding-engines," *ibid.*, 1876, vol. xxv., page 201.
"An Improved Expansion Gearing for Winding-engines," *ibid.*, 1879, vol. xxix., page 3.
"Account of a Discharge of Lightning at Kimblesworth Colliery, on July 12th, 1880," *ibid.*, 1881, vol. xxx., page 129.
"Presidential Address," *ibid.*, 1886, vol. xxxv., page 223.

With a view of celebrating the fiftieth year of the reign of H.M. Queen Victoria, the council of The North of England Institute of Mining and Mechanical Engineers decided to hold a mining exhibition in 1887. As soon as the details of the scheme were published, it was taken up by the Mayor and many of the members of the Council of the city of Newcastle-upon-Tyne; and, at a public meeting, it was determined to expand the project and make it worthy of the metropolis of the North of England. Committees were appointed to carry out this extended scheme, and Mr. John Daglish was appointed chairman of the Executive Council. The Newcastle-upon-Tyne Royal Mining, Engineering and Industrial Exhibition, in which he took a keen interest, proved successful in every respect.

Mr. Daglish took a leading part in the inception and formation of The Institution of Mining Engineers. In his "Presidential Address"* to the members of The North of England Institute of Mining and Mechanical Engineers, on August 7th, 1886, he referred to the several schemes which had been mooted for the concentration of the various mining institutes. He considered that any attempt to amalgamate these institutes into one body would be difficult, if not impossible, but thought that a federation confined chiefly to the publication of their *Transactions* could be carried out to their general advantage. It would place the papers read at each institute in the hands of all mining engineers, and prevent repetition of papers, and duplication of

* *Trans. N. E. Inst.*, 1886, vol. xxxv., page 243.

investigations and experiments by committees on special subjects of general interest. An institute representing the whole of the mining science of Great Britain would be able to supply reliable information to the Government upon the real practical requirements of legislation, and would be a power to resist any proposed legislation contrary to the real interests of mine-owners and workmen. Mr. Daglish lived to see the successful realization of his ideas, and was a member of council and a Vice-president of The Institution of Mining Engineers until his death.

Mr. Daglish, for many years, was a governor of Armstrong College, Newcastle-upon-Tyne, and in 1890 he was appointed to the council, of which he remained an esteemed member until his death. He devoted considerable attention to its management during the later years of his life, and his name will always remain associated with Armstrong College owing to his munificent devise of property for its endowment. He founded the Daglish travelling fellowship in mining, in connection with that college, and the holders, after nomination by The North of England Institute of Mining and Mechanical Engineers, will be appointed by the special election board of the college.

He had also been a Fellow of the Geological Society, and a member of the Institution of Civil Engineers,* the Institution of Mechanical Engineers,† the Tyneside Naturalists' Field Club, the Berwickshire Naturalists' Field Club, the Newcastle Farmers' Club, the Scottish Arboricultural Society, the English Arboricultural Society, etc.

He acted as secretary of the Geological Section of the British Association for the Advancement of Science, at their meeting held in Newcastle-upon-Tyne in 1863, and as an honorary curator and a vice-president of the Natural History Society of Northumberland, Durham and Newcastle-upon-Tyne.

He died in London, on August 9th, 1906, and was interred five days later, in Cambo churchyard, Northumberland.

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* "The Sinking of Two Shafts at Marsden, for the Whitburn Coal Company," *Minutes of Proceedings of the Institution of Civil Engineers*, 1882, vol. lxxi., page 178.

† "The Mechanical Firing of Steam Boilers," *Proceedings of the Institution of Mechanical Engineers*, 1869, page 155

MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

EXCURSION MEETING,

HELD AT MESSRS. POPE & PEARSON'S WEST RIDING COLLIERIES, ALTOFTS, MARCH 23RD, 1907.

The members visited the West Riding collieries at the invitation of Messrs. Pope & Pearson, Limited, and Mr. W. E. Garforth, to witness a demonstration of rescue-work in the experimental gallery at Altofts collieries.

EXPERIMENTAL GALLERY AT ALTOFTS COLLIERIES.

Since the description of the experimental gallery at Altofts collieries for testing life-saving apparatus was described in 1901* considerable alterations have been made. A short description of the gallery as it now exists may, therefore, be of interest to those who may contemplate the erection of a rescue-station.

The external framework of the gallery is the same as originally designed by Mr. W. E. Garforth in 1901; but the internal parts have been altered from time to time, and further obstacles added for the purpose of increasing the difficulties of exploration-work and of obtaining additional efficiency from the men wearing life-saving apparatus.

The gallery, as now arranged, is 100 feet long, with a capacity of 5,600 cubic feet (fig. 1, plate viii.); and it is divided into two parts. The first section, AB, 30 feet long, 6 feet wide and 7½ feet high, is used as a training-ground; it is termed the "nursery," and no obstructions are placed in it. The second section, BCD, 70 feet long, forms the actual testing-ground, and is made to resemble, as far as possible, the damaged roadways of a mine after an explosion (fig. 2, plate viii.). The obstacles placed in this

* "Experimental Gallery for testing Life-saving Apparatus," by Mr. W. E. Garforth, *Trans. Inst. M. E.*, 1901, vol. xxii., page 169.

road consist of overturned tubs, rocks and stones, with broken timber placed irregularly, confined spaces, etc. The general arrangement of this section consists of a clear space, D, representing the downcast shaft, and from this an upper roadway extends to the nursery-section over the débris and other obstacles (fig. 3, plate viii.). For the sake of reporting the work done by explorers, the various parts of this roadway have been given distinctive names, namely, west road, south road and east road. The longitudinal section (fig. 4, plate viii.) shows the various obstructions, etc.

At E (fig. 1, plate viii.), a lower roadway, formed under timber-frames on which the débris rests, communicates, say, from Ludgate through Kirkgate, Holgate, Briggate and Mouseholegate to B, where the two roadways emerge into the nursery-section. Four slits, *a*, *b*, *c* and *d* (figs. 1 and 2, plate viii.) connect the upper and lower roadways with each other and with the coal-faces, represented by Kirkgate and Briggate. The sections (figs. 5 and 6, plate viii.) show the relative positions and areas of the two roadways.

The exterior is fitted with seven exit-doors, each $5\frac{3}{4}$ feet high and $2\frac{5}{12}$ feet wide, together with twelve inspection-windows. The nursery, AB, has two exit-doors, *e* and *f*, and three inspection-windows, *l*, *m* and *n*; and the section, BCD, or the actual testing ground, five exit-doors, *g*, *h*, *i*, *j* and *k*, and nine inspection-windows, *o*, *p*, *q*, *r*, *s*, *t*, *u*, *v* and *w*. The windows, varying from 4 feet by 3 feet to 3 feet by $1\frac{1}{2}$ feet, are so arranged that the attendant is able to watch the explorer and render assistance if required.

In the nursery-section, an appliance is placed for ascertaining the weight that an explorer can lift, when equipped with a life-saving apparatus. It consists of a framework and pulley, over which is passed a rope attached to a weight of 56 pounds. A stretcher weighing 40 pounds, with a dummy-man weighing 160 pounds, is also used for exercise-purposes. The explorers carry a pneumatic horn, similar to that carried by cyclists: it is frequently sounded, once to indicate safety and twice for danger.

An arrangement for conveying a man from the mine up the shaft to the surface has also been provided. It consists of a cradle formed like a saddle, the occupier being placed in a pair of trousers, as in the rocket-apparatus; and it is so arranged that a

man can be upset without being thrown out of it. If a man were put in this apparatus at a depth of 2,000 feet, it would be safe to send him to the surface; and men could descend in it wearing the life-saving apparatus.

An underground pipe connects the two ends, A and D, of the gallery; and, by means of slides, a continuous circulation of gases can be maintained, when it is required to make the atmosphere very deleterious; or fresh air can be admitted to dilute the atmosphere; or the fumes can be entirely replaced by pure air: the whole arrangement being under the complete control of the outside attendant (fig. 1, plate viii.).

When the gallery was constructed, an iron boiler, 30 feet long and 7 feet in diameter, was attached for the purpose of holding a fire fed with compressed air. This fire represented a gob-fire, and afforded a means of testing whether the apparatus would stand a temperature varying from 140° to 150° Fahr.

The results of every trial and any remarks connected with the same are recorded by the attendant in a book at the end of each trial.

MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE INSTITUTE ROOMS, SHEFFIELD, APRIL 9TH, 1907.

MR. J. R. R. WILSON, PRESIDENT, IN THE CHAIR.

The minutes of the General Meetings held on February 20th and March 9th, 1907, were read and confirmed.

The following gentlemen, having been duly nominated, were elected:—

MEMBERS—

Mr. WILLIAM JAMES BELK, Colliery Manager, Thorncliffe Collieries, near Sheffield.

Mr. J. KENNETH GUTHRIE, Mining Engineer, Crigglestone Collieries, near Leeds.

Mr. FRANK H. WATERHOUSE, Colliery Manager, Denby Grange Collieries, near Wakefield.

The PRESIDENT proposed that the thanks of this Institute be given to Messrs. Pope & Pearson, Limited, and to Mr. W. E. Garforth, for their kindness in receiving and entertaining the members of this Institute on March 23rd, and giving a demonstration of life-saving apparatus in their experimental gallery.

The resolution was carried unanimously.

The SECRETARY read the "Report on Rescue-work," etc., as follows:—

REPORT ON RESCUE-WORK DONE BY MEN WEARING RESCUE-APPARATUS IN THE EXPERIMENTAL GALLERY AT MESSRS. POPE & PEARSON'S COLLIERIES, ALTOFTS, ON MARCH 23RD, 1907.

The following programme had been arranged to be carried out before the members of the Midland Institute of Mining, Civil and Mechanical Engineers by two teams: one consisting of four men from Messrs. Pope & Pearson, Limited's collieries, wearing the Weg apparatus; the other of four men equipped with the Draeger apparatus from the Tankersley rescue-station, belonging to the Barrow Hematite Steel Company, Limited, Messrs. Newton, Chambers & Company, Limited, the Strafford Collieries Company, Limited, and the Wharncliffe Silkstone Colliery Company, Limited:—

(1) Four men to enter the gallery, walk 100 yards, and creep on hands and knees, 50 yards.

(2) The same four men to pick up a stretcher, weighing 40 pounds, carry it through narrow roadways, over falls, at the same time removing stones, varying from 40 pounds to 80 pounds in weight; then crawl through an air-pipe, 2 feet in diameter and 6 feet long. Pick up dummy man, 160 pounds in weight, place him on the stretcher, and carry the loaded stretcher back to the entrance of the gallery.

(3) Two of the rescue-team to return to the farthest point of the gallery, carrying fire-extincteurs, and discharge the contents of the same on the windows, in imitation of extinguishing a supposed underground fire. When this work is completed, they will occupy the rest of the time in fixing brattice-cloth, setting props and bars, and other work useful for exploration.

(4) The remaining two men of the team will repeatedly lift a weight of 56 pounds to a height of 6 feet.

The Council of the Midland Institute of Mining, Civil and Mechanical Engineers arrived at the colliery about 10·30 a.m.; and a committee was formed, consisting of the following members:—Prof. G. R. Thompson, Messrs. W. Walker, J. R. R. Wilson, H. B. Nash, J. E. Chambers, J. J. Eley and J. Gill, who supervised the work done by the two teams wearing respectively the Weg and the Draeger apparatus. It was agreed that a coin should be tossed, to show which team should enter the gallery first; and the choice indicated the Weg apparatus.

I.—The following is a detailed record of the work done by the team of four men wearing the Weg apparatus:—

12·17 p.m. Entered the gallery.

12·20 p.m. Walking 80 yards.

12·23 p.m. Creeping 80 yards.

12·27 p.m. Went over the falls, clearing a way for the stretcher, and brought out the dummy man at 12·46 p.m.

12·49 p.m. Nos. 1 and 4 men went over the falls with fire-extincteurs, through the air-pipe, discharged one fire-extincteur, and returned over the falls carrying fire-extincteurs to the nursery or entrance of the gallery.

12·53 p.m. Nos. 2 and 3 men commenced pulling the weight.

1·0 p.m. Nos. 1 and 4 men went over the falls, through the air-pipe, with three rolls of brattice-cloth, a hammer and nails. They fastened up the brattice-cloth in a form representing a mid-feather, to improve or alter the ventilation, and returned over the falls to the nursery at 1·15 p.m.

1·15 p.m. Nos. 1 and 4 men went over the falls carrying two fire-extincteurs, through the air-pipe, and returned over the falls to the nursery.

1·25 p.m. Nos. 1 and 4 men travelled under the falls, and returned over the falls to the nursery.

1·41 p.m. No. 1 man walked 96 yards, and came out of the gallery owing to a break-down in the apparatus; and, the defect being adjusted, he re-entered the gallery at 1·55 p.m.

1·45 p.m. No. 4 man travelled over the falls and under the falls, back to the nursery, with a fire-extincteur.

1·58 p.m. No. 1 man travelled over the falls, through the air-pipe, and under the falls, back to the nursery.

2·5 p.m. Nos. 1 and 4 men travelled over the falls with fire-extincteurs, through the air-pipe, and returned through the air-pipe, and over the falls to the nursery.

2·27 p.m. No. 1 man travelled over the falls with a fire-extincteur, and back.

During this time, No. 2 man had lifted the weight 337 times and No. 3 man had lifted it 251 times, or a total of 588 times, equal to 197,568 foot-pounds of work.

After the team had been in the gallery for 2 hours and 15 minutes, they were requested to come out, as this time had been agreed upon by the Committee as the limit of the trial. The men had understood that they were to stay in as long as they possibly could, and were surprised at the request; and the leader wrote a note saying that No. 3 man could stop in about 20 minutes, No. 2 man about 15 minutes, and No. 1 man about 10 minutes, and that No. 4 man had nearly exhausted his supply of oxygen. After this, each man walked 336 yards.

2·42 p.m. No. 4 man came out of the gallery, having finished his supply of oxygen, and he had been 2 hours and 25 minutes in the gallery.

2·45 p.m. No. 1 man came out of the gallery, oxygen finished.

2·46 p.m. Nos. 2 and 3 men were told to come out of the gallery. Their oxygen-supply was not finished; No. 3 man had a pressure of 40 atmospheres left in one cylinder. Their time in the gallery was 2 hours and 29 minutes.

II.—Men wearing the Draeger apparatus entered the gallery at 3·5 p.m. Nos. 1 and 2 men were wearing the new Draeger mouthpiece, and Nos. 3 and 4 men the Draeger helmet.

3·5 p.m. Walking 96 yards.

Creeping 96 yards.

Went over the falls, clearing a way for the stretcher, and brought out the dummy man at 3·32 p.m.

3·34 p.m. Nos. 1 and 2 men went over the falls and through the air-pipe, and returned over the falls to the nursery; but only one man went through the air-pipe.

4·0 p.m. Nos. 1 and 2 men went over the falls with brattice-cloth; No. 1 man came back over the falls for the hammer, fastened up the brattice-cloth similarly to No. I. team, and returned at 4·20 p.m. to the nursery.

4·25 p.m. Nos. 1 and 2 men went over the falls, and back to the nursery at 4·34 p.m.

4·39 p.m. No. 1 man went over the falls to the sixth door, *j*, and No. 2 man as far as the fourth door, *h*, and returned to the nursery (fig. 1, plate viii.).

4·44 p.m. No. 2 man came out, having been in the gallery 1 hour and 39 minutes.

During this time, Nos. 3 and 4 men had lifted the weight 762 times, equal to 256,032 foot-pounds of work.

5·6 p.m. No. 3 man came out, oxygen finished, having been in the gallery 2 hours and 1 minute.

5·22 p.m. Nos. 1 and 4 men were told to come out of the gallery. They had been in for 2 hours and 17 minutes, and they still had enough oxygen to last for a few minutes longer.

III.—The following is a summary of the work done in a noxious atmosphere, by the men equipped with the following forms of apparatus:—

Occupation of Men.	Apparatus used: Weg.	Draeger.
Walking	1,760 yards.	384 yards.*
Creeping	320 ,,	384 ,,
Travelling over falls	600 ,,	570 ,,
Creeping through contracted passages	80 ,,	—
Creeping through air-pipe	23 times.	14 times.
Carrying fire-extincteurs	8 ,,	2 ,,
Fixed brattice to alter ventilation	Once.	Once.
Lifting 56 pounds weight to a height of 6 feet	588 times.	762 times.
Foot-pounds of work	197,568.	256,032.

Mr. M. H. Habershon read the following paper on "The Use and Care of Oxygen-breathing Apparatus":—

* Mr. M. H. Habershon discusses these results, *Trans. Inst. M. E.*, 1907, vol. xxxiii., page 233.

THE USE AND CARE OF OXYGEN-BREATHING APPARATUS.

By M. H. HABERSHON.

In view of the probability that, in the near future, stations will be established in various places for the purpose of training men in the use of oxygen-breathing apparatus, and at which such apparatus may be kept in readiness for any emergency, it is thought that the following notes of the experience which has been gained during the last few years at the Tankersley rescue-station may be of interest to the members. It is not intended to describe the various types of apparatus, as this has been done so recently by Mr. G. A. Meyer,* Mr. W. E. Garforth† and Mr. R. Cremer.‡

The subject of rescue-appliances has been more or less before this and other mining institutes for some time; but the dispatch of the Westphalian rescue-party to Courrières collieries, and the rescues effected at the recent Reden disaster§ have brought the matter into greater prominence. It may therefore be assumed that members are familiar with the arguments or considerations which point to the necessity of appliances being kept and maintained in readiness for use when suddenly required, and the equal necessity of men being trained to use them.‖

For the present purpose it is only needful to state that the essential conditions which must be satisfied are the following:—

* "Rescue-apparatus and the Experiences gained therewith at the Courrières Collieries by the German Rescue-party," by Mr. G. A. Meyer, *Trans. Inst. M. E.*, 1906, vol. xxxi., page 575.

† "A New Apparatus for Rescue-work in Mines," by Mr. W. E. Garforth, *Trans. Inst. M. E.*, 1906, vol. xxxi., page 625.

‡ "The Pneumatogen: the Self-generating Rescue-apparatus, compared with Other Types," by Mr. R. Cremer, *Trans. Inst. M. E.*, 1906, vol. xxxii., page 51.

§ "Rescue-apparatus in Mines," by Mr. Richard Jacobson, *The Colliery Guardian*, 1907, vol. xciii., page 317.

‖ "A Joint Colliery Rescue-station," by Mr. M. H. Habershon, *Trans. Inst. M. E.*, 1901, vol. xxi., page 100.

(*a*) The apparatus must be conveniently at hand. (*b*) The apparatus must be in perfect working order. (*c*) The men must be thoroughly conversant with the handling of the apparatus, and not merely accustomed to wearing it. (*d*) The instructor or man in charge of the apparatus must be thoroughly trained, not only in wearing and handling the apparatus, but also in cleaning it and testing the various parts for imperfections and leakages. No ordinary caretaker, without special training in the construction and principles of oxygen-breathing apparatus, is capable of occupying this position. The instructor employed at the Tankersley rescue-station had, through the kindness of Mr. G. A. Meyer, the opportunity of going through a course of instruction at the Shamrock colliery, and made himself thoroughly acquainted with every detail of the apparatus in use there at that time, and also of the organized work which is systematically carried on in connection with the Hibernia collieries.

In order to estimate properly the importance of the various points to which the writer proposes to call attention, the following preliminary considerations must be stated. The three chief desiderata in oxygen-breathing apparatus are as follows:— (1) Complete absorption of the carbon dioxide. (2) Sufficient provision of air for the lungs to allow of the performance of hard work by the wearer. (3) Simplicity of construction.

As in ordinary breathing the lungs consume oxygen and produce carbon dioxide, an artificial breathing-apparatus must produce oxygen and absorb the carbon dioxide, and the various types of apparatus all have this end in view. But it is important to notice that the lungs have a large surface for supplying the necessary amount of oxygen to the blood, and the apparatus, being a counterpart to the lungs, should have a large surface for absorbing the carbon dioxide. As, in natural breathing, oxygen is conveyed to the lungs by the aid of the respiratory movements of the muscles of the chest, the artificial apparatus must possess some motive power to bring about a similar action. This is supplied by means of the injector in the Shamrock, Giersberg helmet and Draeger apparatus. The compressed oxygen, passing through the injector, establishes a suction which forcibly draws the exhaled air through the regenerator and round to the injector, where it merges with the fresh oxygen and is then carried forward

for inhalation. The injector thus establishes a continuous circulation of the air in the apparatus.

The necessary supply of oxygen must not be taken as the bare amount actually required for the lungs alone; but a surplus should be provided in order to allow for leakages, so as to ensure that the quantity available shall always be sufficient for the possible requirements of the wearer. It has been ascertained that a continuous supply of 122 cubic inches (2 litres) per minute, is sufficient not only to meet the requirements of heavy work, but also to ensure that the immediate needs of the wearer shall be constantly supplied.

The amount of carbon dioxide produced in the lungs has generally been underestimated. A man doing heavy work will exhale rather more than 6,100 cubic inches (100 litres) of carbon dioxide in 2 hours. For information on this point members are referred to the paper by Dr. J. S. Haldane and Mr. T. Lorraine Smith, on "The Physiological Effects of Air vitiated by Respiration,"* from which the following conclusions have been drawn:—Respiration becomes difficult when the percentage of carbon dioxide in air exceeds 4, with 10 per cent. the possible limit is reached. Breathing air containing 4 to 10 per cent. of carbon dioxide brings on pains and throbbing in the head, accompanied by vomiting. No ordinary excess of oxygen will remove the consequences of breathing this high percentage of carbon dioxide. With an insufficient supply of oxygen, difficulty in breathing first becomes noticeable when the percentage is reduced to about 12, and with 6 per cent. the difficulty is excessive. It has been assumed that a volume of 3,050 to 3,660 cubic inches (50 to 60 litres) of air at disposal during heavy work would be sufficient; but, when a man is breathing heavily after a period of unusual exertion, during a few seconds the amount of air required by him is considerably increased, and it is probable that 6,100 cubic inches (100 litres) may be utilized.

The above figures give some idea of the requirements that have to be met by an oxygen-breathing apparatus, if it is to be reliable under all the conditions in which it is likely to be placed. A rescue-apparatus, therefore, should be capable of complying with the above-mentioned conditions, in addition to having the simplicity of construction which has been referred

* *The Journal of Pathology and Bacteriology*, 1892, vol. i., page 168.

to as one of the chief desiderata; and it may be considered satisfactory or not in proportion to its behaviour when judged accordingly. Other matters, such as facility for cleaning and durability, are important, as they effect the second essential condition above stated, also the necessary consideration of cost of maintenance; but they should not be allowed to interfere too much in selecting a type of apparatus. There are, however, several details which have an influence both on the question of satisfying the essential requirements and on the possibility of keeping the apparatus in proper working order, and it is chiefly to these details that the following notes refer.

The first apparatus used at the Tankersley rescue-station was of the Giersberg 1901 type with two cylinders: it was exhibited to the members of the Institution by Mr. G. A. Meyer on the occasion of their visit to the Düsseldorf exhibition and the Westphalian coal-field. Subsequently a three-cylinder apparatus, of the Giersberg-Shamrock type, embodying several important improvements, which Mr. Meyer had introduced, was obtained; and, at a later period, the Giersberg-Shamrock 1906 type, with two cylinders and additional improvements, as used by Mr. Meyer at the Courrières collieries. On the strong recommendation of the makers, the Giersberg helmet-apparatus was also procured. And, more recently, the Draeger apparatus, arranged for either mouth-breathing or use with a helmet, had been used, in consequence of the powerful regenerators with which this apparatus is supplied. Attention had been directed by Mr. G. B. Walker to this apparatus in 1904.* The pneumatogen had also been tried.

The writer was fully aware of the decided preference expressed by Mr. G. A. Meyer at the London meeting in 1906, for apparatus of the mouth-breathing type, but he had found that men wearing a helmet or face-mask of the latest construction, with separate tubes for inhaling and exhaling and powerful regenerators of the Draeger type, were able to perform really hard work, and to crawl through a length of air-pipe, 2 feet in diameter, without any distress whatever; and that at the end of 2 hours the apparatus would still deliver air to the wearer free from

* *Glückauf*, 1904, vol. xl., page 1331; and *Trans. Inst. M. E.*, 1904, vol. xxviii., page 263.

carbon dioxide, without any liability to headache as formerly. This apparatus is also arranged for mouth-breathing; but it has been found that a greater amount of training is necessary for mouth-breathing, and that many men seem to have a reluctance to having their nostrils closed in a sufficiently secure manner to ensure satisfactory results with the mouth-breathing arrangement, and have a preference for the helmet. The writer thinks that in this country, where the work is done by the men voluntarily, the question of helmet or mouth-breathing may, for the present, be considered as a detail which will be more easily decided after greater experience, and that men should be trained in the use of both types, as there are distinct advantages appertaining to each. The opinion of Mr. G. A. Meyer on this point deserves our greatest respect and consideration; but improvements are developing constantly, and the writer has seen hard work done with a helmet-apparatus under most trying conditions, work which could not have been beaten or so easily done with the mouth-breathing apparatus. He thinks that, probably as recently as a year ago, this would not have been possible.

The improvements effected, which the writer considers to be of decided merit, include an apparatus that can be fitted up for either mouth-breathing or helmet; the complete absorption of all moisture; no liability of any liquid alkali getting into the breathing-tubes; air delivered free from carbon dioxide after 2 hours' work; time required for recharging reduced to about 8 minutes; no assistance required; and the wearer can be trained to ascertain for himself the amount of oxygen still at his disposal, and so to time himself. In case of apparatus used for a short time only, the remaining alkali is not wasted.

In the use and care of the various appliances, the following are the points which the writer wishes to bring under the notice of the members.

In cleaning the Giersberg apparatus of the Shamrock type, after use, attention should first be given to the breathing-bag. The mouth-piece with the attached metal tubing and also the escape-valve must be removed, then the regenerator should be taken out of the inner part of the breathing-bag. All alkali (caustic potash) and kieselguhr must then be removed, and the

holders of the same washed. The breathing-bag must be washed perfectly clean, all sediment being removed, and a mild disinfectant should be used with the water. The bag should then be allowed to dry naturally; no forced method of drying should be adopted. When dry, the passages of the breathing-tube, suction and escape-valve tubes must be ascertained to be perfectly clean. The suction and escape tubes should then be laid on the top of the inner bag, as neglect of this might result in the buckling of these tubes during subsequent handling, and give rise to a stoppage in the working of the apparatus. The regenerator must then be refilled with alkali, and the lower portion with kieselguhr. The inner bag must be examined, in order to see that the holes in the bottom are perfectly clear. The regenerator should then be replaced, the clamps securely fastened, the escape-valve and tubes attached, and the mouth-piece should be plugged. The apparatus, being then ready for use, should be hung up. This complete operation requires at least ½ day on account of the time required for the drying of the breathing-bag.

In the Giersberg helmet-apparatus, the mica valves for inspiration and expiration should be carefully inspected both before and after use, as upon these depends, in a great measure, the proper working of the apparatus. The mica discs and cups must be perfectly dry, as any quantity of moisture may cause these valves to stick. Sufficient room must be allowed in these cups for the valves to move freely, particularly in the case of the expiration-valve: the regulation of this is easily effected by the two screw-caps above and below the mica discs, but care must be taken not to screw these caps too tightly. Before use, the condition of these valves should be tested by placing the helmet on the head securely and drawing several breaths in quick succession, at the same time listening for the click of these valves, which should accompany each inspiration and expiration. The escape-valve should be examined, to see that it will blow off upon a slight compression of the expiration-bag. The pneumatic lining of the helmet and its valve should be carefully examined on each occasion for possible leakages, and any defect immediately attended to. The breathing-bags should be washed and disinfected occasionally, and allowed to dry before they are again used. The regenerator should be washed out after use, great care being taken to see that the passages connecting the two

chambers are perfectly clear and free from any sediment. The flexible tubing should not be handled in too reckless a manner, else injury of a permanent character may be caused; and these tubes, being of special construction, are not easily replaced.

In the Draeger helmet-apparatus, owing to the different arrangement of the valves in the helmet, the same amount of attention to the valves is not so necessary. In the writer's experience of this apparatus, the valves have never been known to stick, indeed any sticking of the valves in this apparatus seems improbable, if not impossible; but the writer thinks that some provision should be made by the makers, so that these valves can be replaced in the event of the mica plates or discs becoming defective. As at present constructed, they cannot be easily got at. The pneumatic lining of the helmet and its valve, as also the breathing-bag, should have the same attention as in the case of the Giersberg apparatus.

In the pneumatogen, in which oxygen is generated by passing the expired air through cartridges containing layers of potassium-sodium peroxide, by which also the carbon dioxide is taken up, there are no valves and no oxygen-cylinders, a small quantity of oxygen only being required to start the chemical action. Consequently the apparatus is extremely simple, and the amount of attention required is reduced to a minimum.

After the pneumatogen has been used, the exhausted cartridges are removed, the upper and lower transverse tubes should be cleaned out, and any particles of carbonate found adhering thereto must be removed. After recharging with fresh cartridges, any screws which have been loosened for cleaning purposes must be firmly screwed down. The cartridges must be placed in their proper position, and the handle of the upper transverse tube pushed down into its right place. The breathing-bag should be washed and disinfected occasionally. The tightness of the apparatus may be tested by closing the mouth of the lower transverse tube with the hand and at the same time blowing into the mouth-piece.

The circulating system of all apparatus should frequently be tested for leakages by blowing into the breathing-tube: the valves of the oxygen-cylinders being closed, thus throwing the apparatus out of action, and using the thumb to close the open end of the tubing, which may have been disconnected for the

purpose of testing. When in action, a solution of soap and water applied to the joints with a brush or sponge will reveal any leakage by the appearance of a small bubble. The valves of the oxygen-cylinders may also be tested for any suspected leakage of oxygen by submerging the cylinders in water. Another method of testing for oxygen-leakages is by the red-hot embers of a match.

Care must be taken to prevent any greasy substance coming in contact with any cylinder or fitting used for the storage or control of oxygen. For instance, the valves of oxygen-cylinders must not be oiled, no lubricant whatever that is of a greasy character must be used. Globe polishing-paste must not be used for the brass fittings or any part of the apparatus.

No part of an apparatus requires more attention from the man in charge than the injector, which, as explained above, supplies the motive power and maintains the circulation of the gases in the apparatus. This should at all times be kept under careful observation. The efficiency of the injector is liable to be affected by oxidation arising from the chemicals used for the absorption of the carbon dioxide, and also by obstruction, which may result from various causes. Any small particles of matter are sufficient to cause a partial blockage, and interfere with the proper working of the injector.

When the cylinders of the apparatus are charged with oxygen from a large storage cylinder, and an hydraulic pump is used in order to obtain the necessary high pressure of 120 atmospheres, the oxygen being removed from the storage cylinder by displacement with water, a grave danger is likely to arise which must be guarded against. The oft-repeated operation, in time, produces an accumulation of rust, and there is the possibility of small particles of rust being conveyed into the cylinder of the apparatus, whence they are only prevented from entering the injector by a thin gauze. If this gauze should be penetrated, a partial or complete blockage of the injector may be produced. If the rust does not reach the injector it will probably accumulate in the reducing valve, but the result will be the same—the apparatus will not work properly. Another and more subtle liability to danger exists with the method of charging the cylinders. Water may pass into the small cylinders during the act of charging. This is unknown to the operator, and its

chambers are perfectly cl[illegible] An apparatus may flexible tubing sho[illegible] time, but after a while else injury of [illegible] and the injector will act tubes, being [illegible] abrupt and premature stoppage

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[illegible] charging small cylinders from a large [illegible] ans of an hydraulic pump worked by hand [illegible] the time required is considerable, and there are newer and improved methods of charging oxygen-cylinders which should be adopted in preference, and with which the above-named liability of water passing into the cylinders is avoided.

In the event of an injector becoming faulty from oxidation or deposit, no hard or sharp tool should be used to clear the offending matter, as damage to the injector may be easily caused in this way, but the injector should be soaked and more gentle means tried. Injectors should be under such close supervision that no oxidation should ever be allowed to accumulate, but the defect discovered and remedied upon the first indication of any fault of this nature. Owing to the delicate mechanism of the reducing valve, it is desirable that a perfect knowledge of its construction should be acquired before any attempt is made to remedy any defect which may be discovered.

Injectors and regulating valves should be included among the necessary spare parts which should be kept at a rescue-station.

All metal tubing on the apparatus should receive close examination from time to time, and be kept perfectly clear from sediment.

The indiarubber breathing-bags and tubes should be kept moist and not allowed to get dry, or the rubber will lose its proper character and the bags will crack and become leaky, particularly at points where any buckling takes place when they are in use. The usual routine of washing and disinfecting the bags is generally sufficient to keep them in good condition, provided that they are used in rotation, and are not allowed to remain idle for too long a period. All apparatus in any station should be used strictly in rotation, and in an equipment consisting of, say, 20

sets, five sets should always be ready for immediate use, and before they are used for practice purposes another set of five must be prepared to replace them. This being strictly attended to, it will keep an equal working strain on each set of apparatus, and will provide for any emergency. A station would in this way be ready at all times to answer and keep up any call on its resources, every apparatus in its turn would come under the notice of the man in charge, and there would be ample time for the work to be done carefully, and without hurry.

It is a good plan to test the circulation of the apparatus, from time to time, by means of a linen bag made to contain from 2,440 to 3,050 cubic inches (40 to 50 litres) of air, and this quantity should be passed into the bag from the apparatus in 1 minute. The air which is being delivered for breathing should also be tested periodically for carbon dioxide when the apparatus is in use. This is easily done by means of a special fitting and a syringe, with which a sample can be taken and injected into a solution of lime-water, when, if turbidity is produced, carbon dioxide is present.

In training men, no work of any kind beyond gentle exercise should be attempted during the first and second practices, but the time should be devoted to instruction in the principle of the apparatus and explanation of the various parts and the circulation of the air. The men should be shown how to handle the apparatus, and practised in the operations of putting it on and taking it off. With helmet-apparatus, the opening and shutting of the helmet-window should be well practised, until the men are thoroughly at home in so doing. The accomplishment of any kind of work must be approached very carefully and by degrees, especially with the mouth-breathing apparatus, with which more practice is usually required in order to become proficient. Suitable men can, however, obtain efficiency with this apparatus in a few weeks, but without occasional subsequent practice the efficiency will be lost, and the men will be surprised that they are not able to wear the apparatus and do work as easily as they anticipated. With the Draeger helmet-apparatus, a man having become thoroughly trained would probably be able to use it after a short lapse of time without intermediate practice.

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presence may not be revealed or suspected. An apparatus may thus work perfectly for some considerable time, but after a while a bubbling sound will be heard and the injector will act spasmodically. Ultimately, an abrupt and premature stoppage of the action of the apparatus may result. If the wearer at this moment happened to be in an irrespirable atmosphere, he would require the assistance of his comrades, or the apparatus might be only a death-trap.

The operation of charging small cylinders from a large storage cylinder by means of an hydraulic pump worked by hand is very laborious, the time required is considerable, and there are newer and improved methods of charging oxygen-cylinders which should be adopted in preference, and with which the above-named liability of water passing into the cylinders is avoided.

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sets, five sets should always be ready for immediate use, and before they are used for practice purposes another set of five must be prepared to replace them. This being strictly attended to, it will keep an equal working strain on each set of apparatus, and will provide for any emergency. A station would in this way be ready at all times to answer and keep up any call on its resources, every apparatus in its turn would come under the notice of the man in charge, and there would be ample time for the work to be done carefully, and without hurry.

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practise in sets of five, so as to get accustomed to work together under a leader. In addition to practices at a station, which should involve hard work in a noxious atmosphere so as to give confidence in the efficiency of the apparatus, it is desirable that men who have been trained and are efficient should occasionally have an opportunity of wearing the apparatus underground, for which purpose each colliery connected with a station should organize a pit-practice, say, once every three months.

The PRESIDENT (Mr. J. R. R. Wilson), in proposing a vote of thanks to Mr. Habershon for his paper, pointed out the extreme importance of such a paper at a time when the question of rescue-stations was attracting so much attention.

Prof. G. R. THOMPSON said that all who were present at the meeting at Altofts colliery were perfectly satisfied that rescue-apparatus would be of use in mines. Recently, it had been contended that the only way of dealing with a mine after an explosion was for the explorers to carry in the air with them. Every miner would admit that the restoration of the ventilation was what they wished to accomplish, and they had seen at Altofts colliery the most convincing evidence that vigorous work was possible in a poisonous atmosphere, when using either the Draeger or the Weg apparatus. Surely such appliances would enable them to re-establish the ventilation much more readily. Mr. Habershon had given the members careful details of the steps to be taken so as to ensure that the apparatus should always be ready for use; and, if his methods of testing and supervision were rigidly adhered to, no fear need be entertained that the apparatus would fail when required. He regretted that accurate information was not recorded in mining text-books, regarding the effects of variations in the composition of the atmosphere breathed, and he wished that Mr. Habershon had told the members more on that point. It was, however, stated that an increase in the amount of carbon dioxide produced ill-effects, which could not be removed by increasing the amount of oxygen; and that a deficiency of oxygen, apart from the presence of carbon dioxide, was also harmful. The methods of absorbing the carbon dioxide generated in breathing seemed sufficiently perfect in the newer forms to keep it below injurious proportions; but he asked whether there

was any danger of the nitrogen, in the compressed oxygen used, accumulating in the Weg apparatus to such an extent that the deficiency of oxygen would become serious. He had much pleasure in seconding the vote of thanks.

Mr. W. McD. MACKEY, referring to the breathing and re-breathing continuously of one charge of nitrogen, said that a man continually for months or years breathing nitrogen, or rather air, under the conditions obtaining in rescue-apparatus, would certainly weaken his lungs and become liable to consumption; that was, the organic matter continually breathed out of his lungs would accumulate and bring on some sort of poisoning. But, in an apparatus of this kind, used for a short time only, he thought that the matter was of no importance. He supposed that the point raised by Prof. Thompson had been dealt with before: he was not aware that provision had been made to get rid of any excess of nitrogen, but he supposed that it was so. Compressed oxygen in cylinders contained not less than 2 per cent. of nitrogen, and it might rise to 4 per cent. and even more. Of course, under these conditions, if nitrogen accumulated in the apparatus, the percentage would become very high in the course of a few hours. Looking at it from the chemical standpoint, he (Mr. Mackey) liked the pneumatogen, as it seemed very simple. It had the objection that it became too warm; but it was light, and mechanically simple. He asked if there were any data by which a comparison could be made between the pneumatogen and the other forms of apparatus.

Sergeant A. T. WINBORN said that Mr. Paul Renaud had stated that the period during which the pneumatogen could be used was too short, and that it was liable to cause sickness owing to the amount of carbon dioxide present,* and Mr. H. Grahn, of the Bochum mining school, had reported that, whereas no ill effects were experienced from the use of the Draeger apparatus, the men wearing the pneumatogen frequently complained of pains in the head.† In the very limited experience at Tankersley with this apparatus, there had been no

* *Comptes Rendus Mensuels des Réunions de la Société de l'Industrie Minérale*, 1907, page 68.

† "Bericht über Versuche mit Rettungsapparaten und über deren Verbesserungen" (Experiments with Rescue-apparatus), by Mr. Hermann Grahn, *Glückauf*, 1906, vol. xlii., page 665.

complaints from this source, but complaints had arisen from the over-heating of the apparatus, brought about by the generation of oxygen. He (Mr. Winborn) thought that the first type of pneumatogen, even in its present condition, formed an almost necessary part of the equipment of a rescue-station, as they could be used by a rescue-party in connection with the bringing out of men who might need such assistance.

The theoretical principles of different types of apparatus had been explained, as also particulars of tests made with them; but the actual number of men who had become efficient, out of a given number undergoing instruction, in the use of any particular type of apparatus had rarely been given in discussion upon this subject. During his experience as instructor at the Tankersley rescue-station, he had learned to judge an apparatus according to the number of men that he had been able to get to wear it in an efficient manner. He thought that the opinion of the men themselves went a long way in estimating the value of an apparatus. They had to put up with any discomfort which might arise through wearing it, and they would be the very first to find out flaws or imperfections. He considered that the best testimonial which any apparatus could have was the decided preference shown for it, over other types, by the men who had to wear it. In his opinion it was not sufficient to have at each pit a few men who could wear an apparatus. The difficulty in getting such men upon the spot when wanted would be great, and too largely a matter of chance; and, at a time of disaster, these men might be in the pit, and themselves in need of succour. An apparatus was wanted such as the maximum number of men could wear, with the minimum amount of practice to attain proficiency. All men were not alike constitutionally. Some could wear an apparatus for a long period, and perform a creditable amount of work; whereas others could wear precisely the same apparatus only for a short time, and the wearing was then often accompanied by ill after-effects. Great strides had been made in the last few years in perfecting the system of regenerating the exhaled air, and all types of apparatus were much more perfect to-day than a few years ago. For instance, during 1904, out of 70 men attending for instruction in the Shamrock type of apparatus, barely 10 per cent. attained efficiency. During 1906, out of the same number of men receiving instruction in the same type of

apparatus, 60 per cent. became efficient. But, in spite of improvements, there still existed this distinction as between different types of apparatus, that although 60 per cent. could wear one apparatus, only 40 per cent. of the same men could wear another type of apparatus in anything like a satisfactory manner. With regard to the Draeger type of apparatus, all the men attending instruction last year were able to wear it for the full period; and he had yet to find the man, constitutionally suitable, who could not wear it. The value of such an apparatus, where a large number of men had to be trained, was inestimable.

He had seen the new Shamrock apparatus, which comprized many important improvements. It could be used either as a mouth-breathing apparatus, or with a helmet; the latter having the additional advantage of being valveless. The position of the injector had been altered, thus minimizing the possibility of any matter effecting a lodgement therein, such as to impede its proper working. The regenerator, instead of being carried inside the breathing-bag, was now carried outside and on the top of it. The apparatus could be recharged in a few minutes, by substituting a fresh regenerator for the used one, which could be recharged with the necessary alkali at leisure and used again, and so on indefinitely. The Draeger also had this advantage, excepting that the cartridges or regenerators were discarded altogether after being used. The oxygen-cylinders of the new Shamrock apparatus were now nickel-plated inside, as a precaution against the accumulation of rust. A trap was placed at the outlet-end to collect any foreign matter, which otherwise might find its way into the reducing valve or injector.

Mr. W. D. Lloyd (Altofts Colliery), on behalf of himself and the men at Altofts, said that he was much gratified by the thanks of the members. He thought that there were many points about the oxygen-supply, which required carefully looking into. He agreed with Mr. Habershon in regard to the question of the recharging of cylinders by pumping water into the storage-cylinders; Messrs. Draeger had introduced an apparatus which overcame that difficulty, but there still remained the difficulty of the moisture in the oxygen. He recently had occasion to measure the cubical contents of a cylinder by filling it with water: when the water was poured out, it was absolutely red with

rust, and, after standing, there was a considerable deposit. The accumulation of rust in the cylinder was a very serious matter, because reducing valves of some sort and small passages with wire-gauze protections were unavoidable in any apparatus: and this rust was liable to get into the passages, and block them so as to render the apparatus inefficient, and possibly cause the death of a man wearing the apparatus. He could corroborate Mr. Mackey's statement that ordinary commercial oxygen contained from 2 to 4 per cent. of nitrogen: there was often 6 per cent. and sometimes more in it; and he had known as much as 10 per cent. of nitrogen to be present. Only a small volume of oxygen was carried in the apparatus, and if 10 per cent. were nitrogen, it became a very serious matter. He most strongly pleaded for as pure a supply of oxygen as possible. He believed that some of the methods of manufacture were within the scope of rescue-stations, and he hoped that they would be able to make their own.

Dr. J. S. Haldane, when testing the Weg apparatus at Altofts, expected to find that an excess of nitrogen might, at times, be present. Dr. Haldane laid stress on the point that, if a man got too much nitrogen or there was a deficiency of oxygen, it would not be noticed in the breathing.* The man would go on breathing it until he became blue in the face and fell down, but he would not experience any difference in his breathing. The smallest percentage of oxygen found in the Weg apparatus by Dr. Haldane was 14 per cent., and this meant, of course, that there was 86 per cent. of nitrogen; and, adopting the percentages quoted by Mr. Habershon, this was still a breathable atmosphere, although the air analysed was obtained from the back bag or reserve-supply, which should be renewed with more oxygen before being breathed again. He thought that Dr. Haldane had obtained as high as 60 per cent. of oxygen.

A point for discussion was that the apparatus described by Mr. Habershon was of the constant-supply type. For ordinary hard work, Mr. Habershon stated that between 3,050 and 3,660 cubic inches (50 to 60 litres) a minute were required, and, at times, even 6,100 cubic inches (100 litres). If the apparatus were set to supply, say, 3,050 cubic inches (50 litres), the men were not in a position to meet any demands for very great exer-

* *Trans. Inst. M. E.*, 1906, vol. xxxi., page 617.

tion, in the same way that they could with a lung-governed and intermittent apparatus, such as the Weg apparatus. The reducing valve in the Weg apparatus was operated by the lungs, oxygen was supplied as required, and it was thus enabled to meet all excessive demands. In the Weg apparatus, if oxygen were not required, it was not used; whereas, with a constant-supply apparatus, if the oxygen were not required, it had to come out and it was wasted. If a man sat down, wearing an apparatus of the constant-supply type, the apparatus would only last the ordinary period of time; whereas, with the other, if the man sat down doing nothing, he did not use much oxygen, and he could wear his apparatus for a much longer time than the ordinary period for hard work. For instance, a man had worn an ordinary Weg apparatus, sitting still, for 6 hours, and he was able to work after that. Thus, one or more members of a rescue-party might be cut off by a fall of roof, and be unable to return to safety as early as they expected: if 2 hours were required to get at a man after he had been using the apparatus, say, 1½ hours, he would be dead long before he could be reached; whereas, wearing an apparatus of the intermittent type, he might be able to stay 3 or 4 hours, with every hope of being ultimately rescued.

With all deference to Mr. G. A. Meyer, the men who were going to wear the apparatus should have a great deal to say about the type. If one wore a nose-clip, and in addition put on smoke-tight goggles, and tried to do one's ordinary work in a pit, one would find oneself considerably crippled and uncomfortable; and he thought that the more comfortable the apparatus the better. Of course, the glass or mica pane in front of the ordinary helmet was certainly a weak point, because once that was broken the helmet became useless. Everything pointed to the use of some sort of a mouthpiece, to include the nose without covering the eyes, and to have the additional advantage that any moisture from the breath, or induced by perspiration of the lower part of the face, should not cloud the glass in front of the eyes.

Mr. F. Hagemann (Hibernia Collieries, Westphalia) wrote that he had pleasure in acknowledging that Mr. Habershon judged impartially, and had brought great experience and a complete knowledge of important details to bear on the subject. The decision as to whether a helmet or a mouthpiece apparatus

was to be preferred, was, in his opinion, not a matter for the rescue-men, but one to be decided only by the engineer of the rescue-corps. The men would be inclined to prefer the most comfortable appliance; whilst the manager of the rescue-arrangements would, if he were the right man in the right place, feel the full responsibility of his position, and would only think of safety: after this point had been satisfactorily settled, he would then consider the comfort of the men. Mr. Habershon had pointed out that, in Great Britain, rescue-work was performed voluntarily by the men; and he appeared to be under the impression that, in Germany and especially at the Hibernia collieries, it was done compulsorily. This was not the case: there was no compulsion throughout Westphalia; there were up to the present date no Government or local rules requiring the provision of rescue-corps at the collieries; and none of the miners at the Hibernia collieries were compelled to become members of the rescue-corps. It had been fully recognized that such an institution would never flourish and become effectual, unless it was carried out and accomplished by voluntary work. He agreed with Mr. Habershon that the question of helmet or mouth-breathing could be decided only after greater experience had been obtained, but he was not able to look at this question as one of detail. He was convinced that the Swiss miner, who was found dead in the Courrières mine (after the German rescue-corps had left) with the torn-off helmet beside him, had not considered the question, when he decided to tear off his helmet. This question had been solved at the Shamrock colliery in two ways: For instance, if it was required to fit an apparatus airtight on the surface of the human body, it would be most easily accomplished by finding the smallest surface. On the other hand, experience had shown that it was very difficult to fasten a helmet tightly on the human head, by pneumatic pressure, without affecting the circulation of the blood in the arteries of the head, and there was the additional danger of damage to the mica or glass window in the helmet. For these reasons, the arrangement of mouth-breathing, and closing the nostrils with greased-wadding plugs combined with a nose-cap, had been adopted at the Hibernia collieries. It was remarkable that, in the latest types of life-saving apparatus, the mouth-breathing method seemed to be preferred. Table I. records the result of

TABLE I.—RESULTS OF PRACTICES WITH SHAMROCK OXYGEN-BREATHING APPARATUS AT SHAMROCK COLLIERY DURING THE YEAR 1906.

Duration of Practices	Number of Practices.		Total Work effected.		Average Work effected per Practice.		Maximum Work effected per Practice.		Minimum Work effected per Practice.	
	No.	Per Cent.	Kilogram-metres.	Foot-pounds.	Kilogram-metres.	Foot-pounds.	Kilogram-metres.	Foot-pounds.	Kilogram-metres.	Foot-pounds.
I.—All Practices.										
2 hours	157	96·32	1,698,840	12,287,948	10,820	78,263	39,000	282,092	4,500	32,549
Less than 2 hours ...	6	3·68	33,360	241,297	5,560	40,216	8,700	62,928	1,050	7,595
Totals and averages ..	163	100·00	1,732,200	12,529,245	10,627	76,866	39,000	282,092	1,050	7,595
II.—Trial Practices only.										
2 hours	10*	76·92	104,370	754,923	10,437	75,492	14,220	102,855	4,500	32,549
Less than 2 hours ..	3†	23·08	10,860	78,552	3,620	26,184	6,300	45,569	1,050	7,595
Totals and averages ..	13‡	100·00	115,230	833,475	8,864	64,114	14,220	102,855	1,050	7,595

* Equal to 6·13 per cent. of the total of 163 practices. † Equal to 1·84 per cent. of the total of 163 practices. ‡ Equal to 7·97 per cent. of the total of 163 practices.

practices with the Shamrock apparatus at the Shamrock collieries during 1906. The apparatus had shown some small defects during the early part of the year: two practices, or 1·22 per cent. of a total of 163 practices, had been interrupted, owing to defects in the apparatus. In the first case, the oxygen-supply was exhausted in 1 hour 45 minutes; and in the second case, owing to a leakage of the emergency-valve, the oxygen-supply was entirely exhausted within 1 hour 33 minutes. The emergency-valve had only been applied for experimental purposes, and was not fitted to the standard type of apparatus. The rescue-corps comprized 31 men and 50 trained officials,

a total of 81 members. Out of 67 mine-officials, 62 men, or 92·54 per cent., had been fully trained in the care and use of oxygen-breathing apparatus. He (Mr. Hagemann) had had opportunities of seeing and experimenting with all the life-saving appliances at present in use, excepting the Weg, which had not yet been used on the Continent.

Mr. H. E. GREGORY wrote that the increasing reliability and usefulness of the newer forms of breathing-appliances were well shown in Mr. Habershon's paper; and it was evident that the desiderata of purity and abundance of the breathing mixture, as well as simplicity of construction, were being brought to a high degree of safety. There was still the possibility of defect in these matters, and whether this possibility had been sufficiently recognized and provided for was, to some, still a matter of doubt. Mr. Habershon did not say whether his appliances could be considered simple in construction, or whether any difficulty might be overcome by perfect training of the wearers and by rigorous care and inspection of the apparatus. The training would be of greater value if the practising chambers for the apparatus were filled with a de-oxidized atmosphere, such as a cooled beehive coke-oven effluent, or boiler-flue gases. Men who had been trained under such conditions would be more confident, and therefore more successful, when they came to practical work in a wrecked mine. The probability of a fatal sequel to a breakdown or defect in the apparatus, when in use, should be provided for. The provision of each apparatus in duplicate would make the appliances too heavy for a man to carry, but perhaps the more delicate parts might be duplicated and thereby increase the safety. With regard to the point raised by Mr. Habershon as to the comparative advantages or disadvantages of the helmet and mouth-breathing types, his (Mr. Gregory's) preference for mouth-breathing was further strengthened by the following quotation:—"Breathing air containing 4 to 10 per cent. of carbon dioxide brings on pains and throbbing in the head, accompanied by vomiting."* Vomiting, when wearing a helmet, would, by choking up the tubes and valves, probably prove fatal; whereas the wearer of a mouth-breathing

* *Trans. Inst. M. E.*, 1907, vol. xxxiii., page 214; and "The Physiological Effects of Air vitiated by Respiration," by Dr. J. S. Haldane and Mr. J. Lorrain Smith, *The Journal of Pathology and Bacteriology*, 1892, vol. i., page 168.

apparatus would possibly be able to remove the mouthpiece before vomiting began, and to re-insert it immediately afterwards, and thus preserve the apparatus from injury. The members and the mining community generally were undoubtedly under a great obligation to Mr. Habershon and the associated colliery companies for their great and humane work directed towards minimizing the penalties of accidents in mines; and the results of their practical efforts and achievements, as shown in this and previous papers, were of the greatest importance and would be a useful guide in the establishment and working of other rescue-stations.

Mr. Richard Jacobson (London) wrote that Mr. Habershon had referred to the grave danger likely to occur when using a hydraulic pump to obtain a pressure of 120 atmospheres in a small oxygen-cylinder: namely, the possibility of rust entering the cylinder and passing into the vital parts of the apparatus, with the ultimate result of hindering the free circulation of air in the breathing-apparatus. In order to avoid the possibility of that danger, Messrs. Draeger had constructed a high-pressure pump, which worked without the use of water. An interesting paper on "Tests of Life-saving Apparatus," in which a self-acting work-recording machine was used and accurate determinations of carbon dioxide made with a special apparatus, had recently been published.* He could not agree with Mr. Hagemann that the decision as to whether a man should wear a helmet or mouth-breathing bag should rest with the instructor or engineer in charge of a rescue-party. That might be the case in practice-work, but in the case of actual rescue-work, where a man wanted all his confidence for the task before him, it was certainly inadvisable to force him to wear an apparatus in which he had no confidence and which made him uncomfortable and nervous. With apparatus in which the helmet and mouth-breathing apparatus were equally efficient, as was the case with the Draeger apparatus, a man certainly ought to be allowed to choose for himself. With regard to Mr. Hagemann's reference to the danger that attended the use of a mica-window in the helmet, he

* "Die Prüfung von Rettungsapparaten durch selbsttätige Arbeitsmessung und exakte Kohlensäure-Bestimmung, von Heinrich und Bernhard Draeger," by Drs. Th. Wetzke, Christern and Wex, *Kohle und Erz*, 1907, No. 6.

(Mr. Jacobson) would point out that the window in the Draeger apparatus was protected against damage by a strong wire guard. The pneumatic arrangement in the Draeger helmet for making an airtight joint between the helmet and the face of the wearer was the only possible successful method. Referring to Mr. Hagemann's remarks on the Swiss miner who, at Courrières, was found dead, with his helmet torn off, he (Mr. Jacobson) might state that it had been established beyond a doubt that the man's apparatus was not in action, and that two other men who were with him, wearing the Shamrock apparatus, were affected by the gas, but had had time to withdraw to a place of safety. Mr. H. E. Gregory's remarks about the advantage of mouth-breathing types of apparatus showed a want of acquaintance with the Draeger helmet. The pneumatic method of making an airtight joint in no way hindered the circulation of the blood; the valves were arranged so that they could not be choked; and, in case of need, the air-lid in the helmet could just as easily be opened by the wearer, as the mouthpiece could be removed.

Mr. M. H. Habershon, replying to the discussion, thought that Mr. Gregory, in speaking of the breathing of carbon dioxide was referring to the Shamrock-Giersberg type of apparatus, and probably had had no experience of recent appliances fitted with improved regenerators. His paper contained no reference to the Weg apparatus, which was not yet standardized, and he had had no opportunity of testing it. He had recently seen the improved Shamrock apparatus, which showed a decided advance on the type used at the Tankersley rescue-station, and he thought it was probable that it would now permit of similar hard work being done to that which they had accomplished with the Draeger appliance. Experiments had not been made with the pneumatogen, on account of the high cost of the cartridges used with that apparatus: their funds were limited, and they were obliged to proceed carefully. During the last few years, however, various appliances had been tested as they had become available, and a number of men had been trained. At the present time, about 68 men, altogether, had been trained, connected with the four colliery companies interested in the rescue-station. The earlier appliances were, however, now entirely obsolete, and their rescue-station was not adequately equipped with a sufficient number of

up-to-date and reliable apparatus. Sergeant Winborn's remarks as to the probable value of the lighter form of the pneumatogen seemed very apropos to the opinion expressed by Mr. F. A. Gray, H.M. inspector of mines, in his evidence before the Royal Commission on the question of the possibility of saving the lives of men.* The first type of pneumatogen had a total weight of only 3¼ pounds, and would supply air for 45 minutes. It could be easily carried by a rescue-party, and used in the work of bringing men out through an irrespirable atmosphere.†

Referring to the report on the demonstration of the use of rescue-apparatus at Altofts colliery, he thought that the distances walked, namely, 1,760 yards with the Weg and 384 yards with the Draeger, were somewhat misleading, as the men wearing the Draeger apparatus only walked the distance arranged by the programme, not knowing that any further distance would be recorded.

The best duration-tests made at the Tankersley rescue-station were as follows:—(1) W. Clifford, of Strafford colliery, with Draeger mouth-breathing type, 4 hours 3 minutes; no work done. (2) J. Anderson, of Barrow collieries, with Draeger mouth-breathing type, 5 hours, during which time he walked 7,400 yards. At the conclusion of this test the man was very hungry: this seemed the most noticeable fact, after wearing the apparatus for a long period. (3) As regards weight-lifting tests: J. Anderson, on one occasion, had raised a 56 pounds weight to a height of 7 feet, 610 times, equal to 239,120 foot-pounds, in 1 hour and 40 minutes. At Altofts collieries, he and another man performed together 256,032 foot-pounds; but, as Mr. Lloyd had pointed out, they had previously been over falls, and assisted in bringing out the dummy man on a sledge. He thought that the fact that it was thus possible to do extremely hard work for 2 hours with this apparatus, somewhat answered Mr. Lloyd's remarks about the disadvantage of using an apparatus with a constant supply of oxygen; and that much could be said in favour of the constant supply, which required no thought, or manipulation, or attention whatever, from the wearer for 2 hours,

* *Minutes of Evidence taken before the Royal Commission on Mines*, Wednesday, 28th November, 1906, proof; and *The Colliery Guardian*, 1907, vol. xciii., page 395.

† *Trans. Inst. M. E.*, 1906, vol. xxxii., page 55.

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THE MINING INSTITUTE OF SCOTLAND.

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POLMAISE COLLIERIES, JUNE 29TH, 1907.

The members, numbering about 160, were driven from Stirling to the Polmaise collieries of Messrs. Archibald Russell, Limited, where they were met by Mr. James Salmond, general manager, and Mr. David Todd, local manager, and shown over the works. Luncheon was kindly provided at Stirling.

The PRESIDENT (Dr. Robert Thomas Moore) moved that the thanks of the Institute be heartily given to their entertainers and their officials.

and thus added to the desired simplicity of construction. He thought that an apparatus sufficient for the above work for 2 hours might be considered a serviceable apparatus, and that, with the improvements which were constantly being introduced, there was every encouragement to go forward. He thanked the members for the kindly manner in which they had received his paper.

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THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,

HELD IN STIRLING, JUNE 29TH, 1907.

DR. ROBERT THOMAS MOORE, PRESIDENT, IN THE CHAIR.

The following gentlemen were elected:—

MEMBERS—

Mr. J. A. C. BAYNE, Kerse Road, Grangemouth.
Mr. ROBERT H. CRAWFORD, 208, St. Vincent Street, Glasgow.
Mr. JAMES DALGLEISH, Woodbank, Park Street, Wishaw.
Mr. WILLIAM DAVIDSON, Plean Colliery, Plean.
Mr. JOHN GIBSON, Earlston, Kilmarnock.
Mr. JOHN GRAY, Gordon Cottage, Cowdenbeath.
Mr. ALEXANDER HAMILTON, Roman Camp, Uphall.
Mr. JAMES HENDERSON, Auchengeich, Chryston.
Mr. PETER HENDERSON, Lochgelly Collieries, Lochgelly.
Mr. WILLIAM KING, 7, Dalkeith Avenue, Dumbreck, Glasgow.
Mr. JAMES LECKIE, Bertrohill, Shettleston.
Mr. GEORGE A. LINDSAY, 5, Leslie Road, Pollokshields, Glasgow.
Mr. H. A. MCGUFFIE, 87, Union Street, Glasgow.
Mr. ANGUS MACKAY, Jamaloba Colliery, Gharia P.O., Bengal, India.
Mr. PERCY H. M. MACKINTOSH, Public Works Department, Greymouth, New Zealand.
Mr. THOMAS MALONE, Buen Retiro, Coronel, Chile.
Mr. JAMES PARK, Viletta, Woodbine Avenue, Airdrie.
Mr. THOMAS REID, P.O. Box 24, Bethlehem, Orange River Colony.
Mr. DAVID SPEIR, Balgonie Colliery, Thornton.

ASSOCIATE—

Mr. ROBERT LEGGATT, Clover Park, Dunaskin, Ayr.

The following description of "Polmaise Collieries" by Mr. James Salmond was held as read:—

POLMAISE COLLIERIES.

By JAMES SALMOND.

Polmaise collieries, the property of Messrs. Archibald Russell, Limited, consist, at present, of four shafts, situated in the parish of St. Ninians: Nos. 1 and 2 pits being about 1¼ miles, and Nos. 3 and 4 pits 3 miles, distant south-east from the county-town of Stirling. The mineral-fields comprize the following leaseholds:—Polmaise, 2,100 acres; Townlands, 600 acres; Blackgrange and Westgrange, 400 acres; Stewarthall, 270 acres; Broadleys, 125 acres; and Clayslaps, 30 acres; a total area of 3,525 acres. Numerous bores, put down at former times on the Townlands and Stewarthall, along with seven diamond bores put down by the present tenants on Polmaise, Blackgrange and Westgrange, go to prove the existence of the various seams of coal under practically the whole of the field. The strata, which are in the Carboniferous Limestone series, have an inclination of 1 in 4¼ towards the north-east.

Nos. 1 and 2 Pits.

The sinking of Nos. 1 and 2 pits, 66 feet apart, was commenced in December, 1902, and finished in June, 1904. The No. 1 shaft, 18 feet long and 6½ feet wide, contains two winding spaces of 7 feet, and one space of 1 foot and one of 2 feet are utilized for water-pipes; and the No. 2 or upcast shaft, 19½ feet long and 6½ feet wide, contains two winding spaces of 7 feet, one space of 3½ feet, and another of 1 foot in which are the cables. The surface (Table I.), which was soft and troublesome, was

Table I.—Surface-strata Sunk through in Nos. 1 and 2 Pits, Polmaise Collieries.

No.	Description of Strata.	Thickness of Strata. Ft.	Ins.	Depth from Surface. Ft	Ins.	No.	Description of Strata.	Thickness of Strata. Ft.	Ins.	Depth from Surface. Ft.	Ins.
1	Soil	1	6	1	6	6	Coarse sand and shells	0	6	39	0
2	Yellow clay	3	6	5	0	7	Red clay and stones...	4	6	43	6
3	Blue silt, very soft ...	21	0	26	0	8	Red clay, very soft ...	36	6	80	0
4	Peat	0	6	26	6	9	Sand, gravel and boulders	19	0	99	0
5	Fine sand, with water	12	0	38	6	10	Broken rock	2	6	101	6

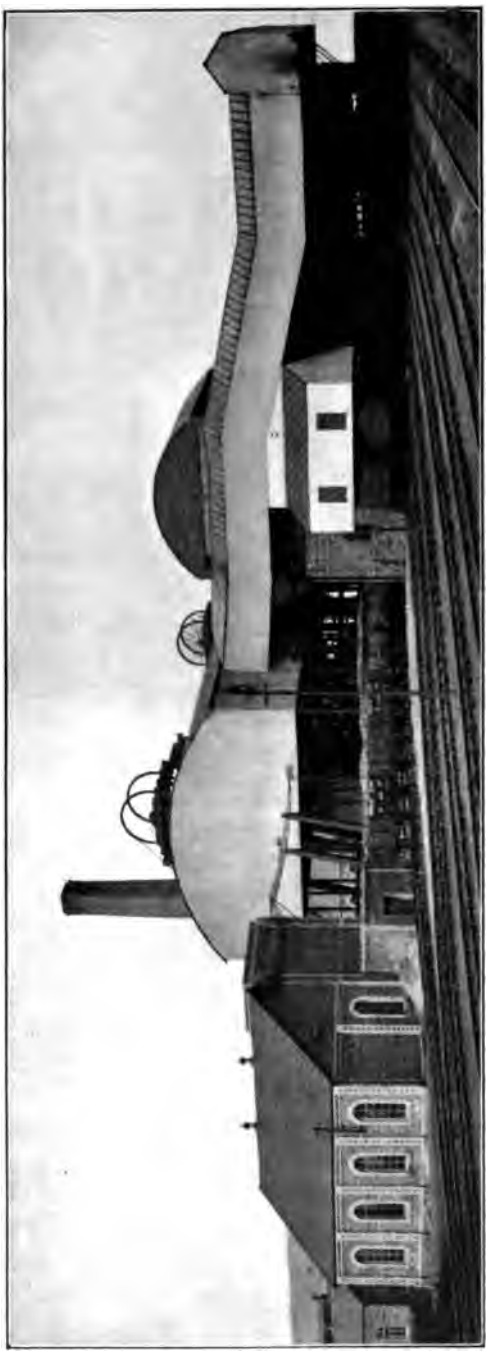

FIG. 1.—NOS. 1 AND 2 PITS, POLMAISE COLLIERIES.

sunk through by means of a steel crib 24¼ feet long, 9½ feet wide and 7 feet deep.

The water got during the sinking was brackish, and was observed to be most abundant in quantity at the time of high tide in the river Forth, which is about 1 mile distant. When sunk through the surface, No. 1 pit was lined with pitchpine, 9 inches wide and 6 inches thick; and all the other pits were lined with pitchpine 9 inches square. A second set of barring, 9 inches wide and 4 inches thick, was then built in to the finished size of the pit, the space between the two barrings being filled with clay. The remainder of the shafts is lined throughout with pitchpine, 9 inches wide and 3 inches thick: the buntons,

9 inches wide and 4 inches thick, being placed 4 feet apart. The wall-plates are 24 feet long, 9 inches wide and 3 inches thick, and the corner-rackings, 3 inches square. The slides are pitchpine, 5 inches wide and 4 inches thick.

Seams of Coal.—Twelve seams of coal were passed through in the shafts, amounting in thickness to 23 feet 3 inches. The thicknesses of the seams which are at present being worked, and the depths at No. 1 pit, are as follows:—The Hartley seam, 2 feet at 291 feet; the Greenyard seam, 3 feet 3 inches at 372 feet; the Main seam, 3 feet 1 inch at 447 feet; and the Knott seam, 3 feet at 486 feet. The whole of these seams are wrought by the longwall system.

The first two seams are navigation coals and the others anthracite, with the following analyses:—(*a*) Navigation coal, volatile matter, gas, tar, etc., 24·41 per cent.; sulphur, 0·16 per cent.; and water, 3·62 per cent.: a total of 28·19 per cent; coke, fixed carbon, 68·85 per cent.; sulphur, 0·41 per cent.; and ash, 2·55 per cent.: a total of 71·81 per cent. The specific gravity is 1·33. The practical heating power, by Playfair's formula (water at 212 degrees Fahr. evaporated by 1 pound of coal), is 9·60 pounds. (*b*) Anthracite coal, volatile matter, gas, tar, etc., 10·11 per cent.; sulphur, 0·09 per cent.; and water, 2·00 per cent.: a total of 12·20 per cent.; coke, fixed carbon, 83·69 per cent.; sulphur, 0·61 per cent.; and ash, 3·50 per cent.: a total of 87·80 per cent. The specific gravity is 1·30. The practical heating power by Playfair's formula (water at 212 degrees Fahr. evaporated by 1 pound of coal) is 11·18 pounds.

Boilers.—Steam is supplied by six Lancashire boilers, 30 feet long and 8 feet in diameter, working at a pressure of 100 pounds per square inch. The chimney is 125 feet high, 12¼ feet square at the base and 7½ feet square outside at the top. For the purpose of dealing with the anthracite gum and table-pickings, forced-draught has been fitted to the boilers. A Sirocco fan, 35 inches in diameter, produces the draught, which is led through pipes into perforated hollow fire-plates. The motor for driving the fan, of 20 horsepower, of the squirrel-cage type, runs at 940 revolutions per minute, and is started by means of an oil-immersed auto-starter. Owing to the pit-water

being unsuitable for the boilers, a turbine pump, situated at the Bannock burn, pumps a supply of water to Nos. 1, 2, 3 and 4 pits. This pump is capable of delivering 150 gallons per minute, and is driven direct by a squirrel-cage motor of 8½ horsepower, running at 1,450 revolutions per minute. The exhaust steam is led to a heating cylinder in connection with two feed-pumps, and heats the water before it is fed into the boilers.

Winding-engines.—The winding-engines are alike at both pits, each having two horizontal cylinders, 22 inches in diameter and 4½ feet stroke, fitted with balanced slide-valves, and drums 12 feet in diameter. The engine-houses are built of brick and are of ample size, with open bound roofs, and lined with red pine. The pithead frames are of the trestle type, constructed of pitchpine and oak, and the pulleys are 12 feet in diameter. The winding-rope is 3⅛ inches in circumference, and the cage is constructed to carry two hutches with a capacity of 10 cwts. each. The hutches have steel sides and bottoms, with wooden ends, and the rails are of the bridge type.

Electric Generating Plant.—Two compound steam turbines, each of about 350 horsepower, and running at 3,000 revolutions per minute, are coupled direct by means of flexible clutch-couplings to three-phase, 50 periods, 500 volts alternators of 200 kilowatts output. The direct-driven exciters are mounted on an extension of the armature-spindle. The shaft at the other end bearing carries a screw-thread, working a worm-wheel which actuates a pump for forcing oil through the bearings and the steam-admission governor by means of an eccentric. A pump, situated in the boiler-feed house, circulates water round the oil-tanks to keep them cool. The machines are at present non-condensing, but the question of condensing is under consideration.

Switchboard and Switchgear.—The main switchboard in the power-house consists of five white Sicilian-marble panels:—Two panels for controlling the two generators are so arranged that the machines can be run in parallel, and each having mounted thereon, three ammeters; an exciter voltmeter; a three-pole oil-switch and fuses; a pilot switch; a synchroniz-

ing arrangement; and an earth-detecting device mounted on a swinging bracket at the end of the board. Two feeder-panels, each having mounted thereon two ammeters; and two oil-immersed switches with fuses. One lighting panel, having mounted thereon three transformers, each having a capacity of 7½ kilowatts for reducing the current to 100 volts continuous current for the purposes of lighting; three ammeters; and three back-of-panel type switches on the high-tension side of the transformers.

The underground switchgear is of the totally-enclosed unit type. In the Greenyard seam there are two pillars, and in the Knott seam three pillars, each containing an ammeter, an oil-break switch, fuses, isolating links, omnibus-bar chambers, trifucating box, etc. On pillars which control the haulages, the oil-break switch is replaced by oil-break circuit-breakers.

Ventilation.—The fan is driven direct, by a non-condensing compound steam-turbine similar to those driving the alternators. Two single-inlet fans of the propeller type, 47 inches in diameter, when running at 2,500 revolutions per minute, are capable of exhausting 150,000 cubic feet of air per minute against a watergauge of 3 inches.

Safety-lamps.—Safety-lamps are in use throughout these pits, they are magnetically locked and electrically ignited: the underground appliance for relighting them being so constructed that it cannot be operated nor can a spark be produced unless the lamp is in position underneath an airtight closed-down lid. Two machines are fitted in the lamp-cabin: one for charging the accumulators, and the other for cleaning 100 lamps per hour, each being driven by a motor of 1½ horsepower.

Haulage.—The only dip workings at present are in the Hartley seam, and the coal is taken out therefrom by means of a main-rope haulage driven by an enclosed slip-ring motor of 85 horsepower running at 560 revolutions per minute, and operated by a single-hand drum-type oil-immersed controller with oil-immersed resistances suitable for starting against a 200 per cent. full-load torque in 30 seconds, and regulating down to half-speed for one minute in each six.

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Screening and Washing Plants.—The screening and washing plants, together with the housing and gangways, are arranged for dealing with 1,000 tons, but have been found capable of dealing with 1,200 tons in a day of 9½ hours. The screening and washing plant-houses are of brick and steel, and the pithead house and gangways are of steel: the whole is roofed over and covered in with corrugated-iron sheeting and glass, no part of the plant or gangways being exposed to the weather. The loaded hutches run by self-acting gradients from the pit-mouth to the bottom of a creeper-haulage, which elevates them to a sufficient height to carry them over the weighing-machine to the revolving tippers fitted with automatic starting-and-stopping gear. From the tippers, the tubs gravitate around the cleaning plant to another creeper which elevates them to a height sufficient to enable them to gravitate to the back of the pits. Fixed screens are provided in the pithead-house, for dealing with coal for local sales. The navigation coal is passed over two picking-belts of the bar-grating type: the delivery-ends being provided with radial portions, operated by means of power-driven worm-gear for lowering them into the trucks to minimize the breaking when loading. The small coal from the shakers and the belts is collected by means of a scraper-conveyor, and is delivered into wagons for conveyance to the washer at Nos. 3 and 4 pits.

The anthracite-coal plant consists of two sets, one of which is used for round coal when required, and is similar to those already described. The other set is also similar, but contains

wo sets of crusher-rolls which are employed for reducing the nd coal to the size of jumbos and trebles, the latter of which passed over a picking-belt of the same kind as the others. umbos are delivered to a small conveyor, which in turn them to the round-coal belt. The coal that is smaller in the trebles passes into a scraper-conveyor, and is conyed to the dross-pit of the washer. The refuse, picked off the picking belts, is thrown into a conveyor, running at right angles under the picking-floor, and conveyed to a hopper at the pithead, whence it is taken to the dirt-bing in hutches.

The anthracite-washing plant, with a capacity of 30 tons per hour, is arranged to separate the small coal into doubles, singles, pearls and gum. The small coal, elevated by means of a bucket-elevator from the dross-pit, is delivered into a rotary screen, where it is separated into four sizes, the pearls and gum being delivered into a nest of six felspar-washers, the singles into two bash-tanks, and the doubles to the Primus washer. The fine coal and water is led by pipes to a silt-recoverer, which recovers the fine coal and delivers it into a conveyor supplying the boiler stokehold. The refuse, taken out of the coal by washing, is elevated by means of bucket-elevators and delivered into the same hopper as that which receives the refuse from the screening plant.

The washing and screening plants are each driven by means of a slip-ring motor of 100 horsepower, running at 470 revolutions per minute, and operated by a faceplate starter. The silt-recovery plant is driven by a squirrel-cage motor of 10 horsepower, running at 940 revolutions per minute, and started by means of an oil-immersed auto-starter.

Primus Washer.—A Primus washer has been fitted up, on trial, to separate from the doubles a sclit* which closely approximates the weight of coal. Its capacity is about 15 tons per hour, and in principle it differs from other washers in use, the uncleaned coal being fed into a perforated-bottom reciprocating box, in motion in water, causing the coal to be displaced by the sclit which forms the bottom. The depth of bottom and the line of separation are under positive control, and subject to delicate adjustment by levers. Once adjusted, the separation is

* Slaty coal.

Pumping.—The Worthington six-stage turbine pump, placed in the Knott coal-seam, is capable of pumping 200 gallons of water per minute to the surface, and is driven direct by a motor running at 1,440 revolutions per minute. The motor is mounted on a combination base-plate, and is operated by means of an oil-immersed auto-starter.

Another pump, in the Hartley dook, delivers into the lodgment of the turbine pump. This three-throw pump, having rams 5½ inches in diameter and 9 inches stroke, is driven through gearing by a squirrel-cage motor of 9 horsepower, running at 940 revolutions per minute, and operated by an oil-immersed auto-starter.

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* Slaty coal.

automatic, the products passing to the draining elevators and thence to the wagons. The plant is driven by a small horizontal steam-engine, with a cylinder 7 inches in diameter and 8 inches stroke.

Railways.—In addition to the locomotive-road, there are eight other roads, for dealing with the different classes of fuel, laid at an inclination of 1 in 75.

Offices and Workshops.—The offices and workshops, of ample size, comprize the counting-house, store, ambulance-room, smithy, and engineer's and joiner's shops.

Dwelling-houses.—Thirty cottages, with all modern conveniences, are erected at the entrance to the colliery, principally for the use of officials.

Nos. 3 and 4 Pits.

Nos. 3 and 4 pits lie about 1¾ miles to the east of Nos. 1 and 2 pits, and are connected thereto by a private railway 2¼ miles in length. The sinking was commenced in August, 1904. No. 3 pit was finished in December, 1905, and No. 4 pit in April, 1906. The shafts passed through twenty seams of coal, over 1 foot in thickness, the total amounting to 32 feet 6 inches. The seams at present being worked, and the depths at No. 3 pit, are as follows:—The Hirst seam, 2 feet 2 inches at 102 feet; the Hartley seam, 2 feet 4 inches at 1,008 feet; and the Knott seam, 2 feet 6 inches at 1,242 feet. The Index limestone, 33 inches thick, was got at 786 feet.

The surface was of the same soft nature, although not so deep as that at Nos. 1 and 2 pits, being in this case 60 feet thick. The same method of sinking was adopted, a crib of like dimensions being used: but a second set of barring was not put into No. 4 pit, as it had been decided to have separate winding-spaces for the Hirst coal-seam. The No. 3 and downcast pit, 22 feet long and 6½ feet wide, has four divisions, two of them for winding purposes being 7 feet, another of 6 feet, and the fourth, 1 foot, is used for the cables. The No. 4 pit, 16 feet long and 6½ feet wide, has three divisions, two of them, each 7 feet, being used for wind-

ing, and the other, 1 foot, contains the steam- and water-pipes. Down to the Hirst coal-seam, the pit is 22¾ feet long and 8 feet wide, owing to there being two separate winding spaces of 3 feet 10 inches by 6 feet to this seam, over and above those already mentioned. Both pits are lined throughout, and are fitted with the same sizes of wood as in Nos. 1 and 2 pits.

Boilers.—There are six Lancashire boilers, 30 feet long and 8 feet in diameter, fitted with rocking firebars and working at a pressure of 100 pounds per square inch. The chimney is of the same dimensions as that at Nos. 1 and 2 pits, and the exhaust steam is also passed through a heater, there being two feed-pumps.

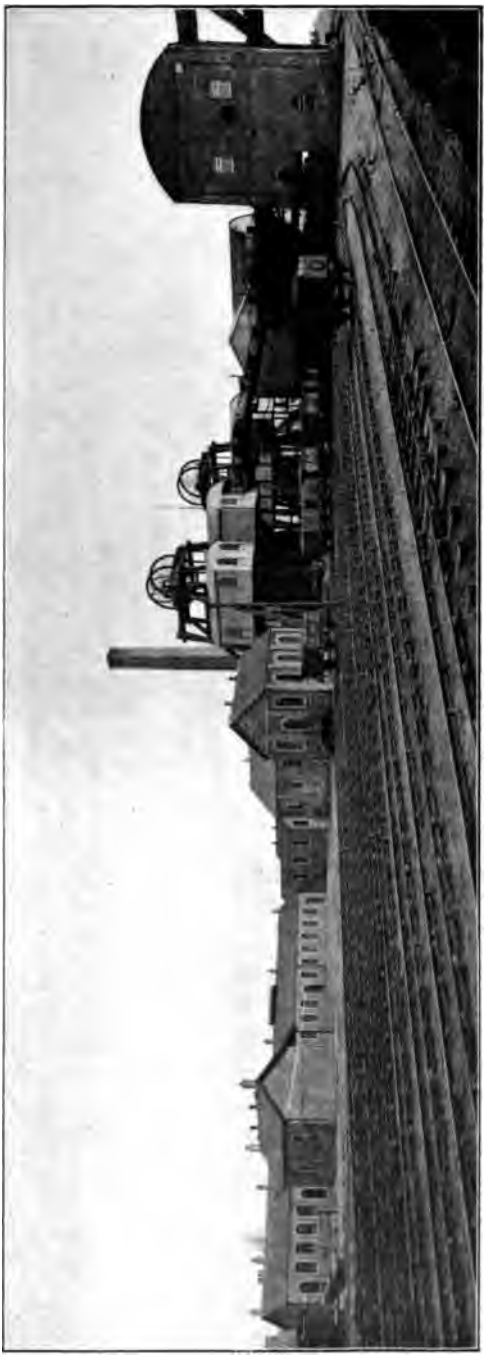

FIG. 2.—NOS. 3 AND 4 PITS, POLMAISE COLLIERIES.

Winding-engines.—There are three winding-engines, two winding from each of the pits and the other from the end of No. 4 pit. The former of these are both alike, each having two horizontal cylinders 26 inches in diameter by 5 feet stroke, fitted with balanced valve-gear, and drums 16 feet in diameter. The winding-engine to the Hirst coal-seam is of the same type, with cylinders 12 inches in diameter and 2½ feet stroke, the drums being 5 feet in diameter. The pithead frames are of the same style as at Nos. 1 and 2 pits, with pulleys 16 feet and 8 feet in diameter respectively for the large and small pits; the ropes are 3½ inches in circumference.

Electric Generating Plant.—The generating plant at present consists of an alternator with a fixed armature and revolving field magnets, and a direct-coupled exciter. It is designed to give an output of 200 kilowatts at a pressure of 500 volts, 50 periods, three-phase, when running at the speed of the engine, namely, 428 revolutions per minute. The engine of 300 brake-horsepower is of the compound, double-crank, enclosed and forced-lubrication type, the cylinders being 16½ and 24½ inches in diameter and 10½ inches stroke. Provision has been made for accommodating another generator in the same house.

Switchgear.—The switchboard consists of a generator panel, a lighting panel and a feeder panel fitted generally in the same manner as at Nos. 1 and 2 pits. In the Hirst seam, there are five feeder and control pillars, and in the Hartley seam two, all of the same unit type as those in use at Nos. 1 and 2 pits.

Ventilation.—The ventilation is produced by a Capell fan, 8 feet in diameter and 7 feet in width, running at 320 revolutions per minute and capable of exhausting 150,000 cubic feet of air per minute at a watergauge of 3 inches. It is rope-driven by a single horizontal engine, with a cylinder 18 inches in diameter and 2 feet 10 inches stroke, fitted with Meyer expansion-gear, and running at 80 revolutions per minute.

Safety-lamps.—With the exception of the Hirst seam, safety-lamps are used throughout. In this case, the cleaning and charging machines are driven by two steam-engines, with cylinders 5 inches in diameter and 6 inches stroke.

Haulage.—There are two main-rope haulages: that in the Hirst seam is driven by a slip-ring motor of 85 horsepower, running at 560 revolutions per minute; and the other in the Hartley seam is driven by a motor of 100 horsepower of the same type, but running at 470 revolutions per minute. Both of the motors are governed by a controller similar to that in No. 2 pit.

Pumping.—In the Hirst seam, there is a three-throw pump and motor of the same dimensions as that in No. 2 pit forcing water to the surface. Another pump, placed in the Knott coal-seam, forces its water to a lodgment at a depth of 810 feet. It is a three-throw pump, having rams 4 inches in diameter and 9 inches stroke, and is belt-driven by a squirrel-cage motor of 15 horsepower running at 710 revolutions per minute, and operated by means of an oil-immersed auto-starter. The water in the lodgment at 810 feet is dealt with by a Worthington pump, having two steam-cylinders 20 inches in diameter, and two double-acting water-plungers 7 inches in diameter, all having a stroke of 15 inches.

Screening and Washing Plants.—The screening plant is on similar lines to that at Nos. 1 and 2 pits, the gangways in this case being open, only the pitheads being covered. There are three picking-belts each being used respectively for Hirst (or splint) coal, anthracite coal and best house coal. The small coal from the anthracite table is delivered into wagons, and taken to the washer at Nos. 1 and 2 pits. The dross from the other tables is treated by a washer on the ground. The whole of the cleaning plant is driven by a horizontal steam-engine, with two cylinders 8 inches in diameter and 16 inches stroke.

The washer is of the same kind as that at Nos. 1 and 2 pits, but it is able to wash 50 tons per hour, having three bash-tanks for treating the trebles, doubles and singles, and two nests of six felspar washers for treating the pearls and gum. The plant is driven by a horizontal engine, with two cylinders 10 inches in diameter and 18 inches stroke. The silt-recoverer, and the conveyor for the gum received from it and conveyed to the boilers, is driven by an engine with a cylinder 6 inches in diameter and 12 inches stroke.

Railway-sidings.—There are eight roads in addition to the engine-road, for dealing with the various classes of fuel.

Dwelling-houses.—There are twenty cottages for officials erected at the entrance to the colliery; eighty workmen's houses of the room-and-kitchen type, with all conveniences, have been built near the colliery; and a hundred more are in course of erection. Water for domestic purposes is led in pipes for a distance of 2 miles from the town-mains: and, owing to the supply being scarce, storage-tanks have been erected. The pit-water, pumped into tanks, is conveyed to the houses for flushing purposes.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
JUNE 8TH, 1907.

MR. J. H. MERIVALE, PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting and reported the proceedings of the Council at their meetings on May 25th and that day.

The SECRETARY read the balloting list for the election of officers for the year 1907-1908.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. JOHN ABEL CHAPMAN, Engineer, 56, Bewick Road, Gateshead-upon-Tyne.

Mr. FRANCIS HENRY LAMBTON CROUDACE, Colliery Manager, The Lodge, Lambton, Newcastle, New South Wales, Australia.

Mr. SYDNEY CROUDACE, Colliery Manager and Mining Engineer, New Lambton, Newcastle, New South Wales, Australia.

Mr. ROBERT WILLIAM HALL, Colliery Manager, Thrislington Colliery, West Cornforth, S.O., County Durham.

Mr. HAROLD HORWOOD-BARRETT, Mining and Consulting Engineer, 2, Park View Villas, Hove, Brighton.

Mr. CHARLES HOWSON, Colliery Manager, Harraton Colliery, Chester-le-Street.

Mr. DUDLEY JAMES INSKIPP, Mining Engineer, Grand Hotel, Bulawayo, Rhodesia, South Africa.

Mr. WILLIAM HENRY RAMSAY, Colliery Manager, Harperley Hall, Tantobie, S.O., County Durham.

Mr. ROBERT SMART, Assayer to the Yukon Government, White Horse, Yukon Territory, Canada.

Mr. William Teutenberg, Mining Engineer and Surveyor, Nenthead, Alston, S.O., Cumberland.
Mr. Errington Thompson, Metal-mine Manager, Weardale House, St. John's Chapel, S.O., County Durham.
Mr. Henry Walker, H.M. Inspector of Mines, Durham.
Mr. Henry Stevenson Willis, Colliery Manager, The Garth, Medomsley, S.O., County Durham.
Mr. William Wilson, Colliery Manager, Chilton Colliery, *via* Ferry Hill.

Associate Members—

Mr. Featherstone Fenwick, County Chambers, Newcastle-upon-Tyne.
Mr. James Kirkley, Cleadon Park, Cleadon, Sunderland.

Associates—

Mr. Philip Sidney Blunden, Under-manager, The Villas, Dean Bank, Ferry Hill Village, Ferry Hill.
Mr. George Elliott, Under-manager, Dinnington Colliery, Dudley, S.O., Northumberland.
Mr. George Tweddell, Back-overman, 51, Double Row, Seaton Delaval, S.O., Northumberland.

Students—

Mr. William Ernest Avery, Mining Student, Ravensworth Colliery Office, Low Fell, Gateshead-upon-Tyne.
Mr. John Brown, Mining Student, 4, Scotch Street, Whitehaven.
Mr. Thomas Watson, Jun., Mining Student, Rosebank, Darlington.
Mr. Hubert Watts, Mechanical Engineering Student, Cleveland House, North Shields.

DISCUSSION OF MR. R. CREMER'S PAPER ON "THE PNEUMATOGEN: THE SELF-GENERATING RESCUE-APPARATUS, COMPARED WITH OTHER TYPES."*

Mr. M. Walton Brown said that Mr. Fickler, of Gneisenau colliery, Westphalia, had stated that on April 17th, 1907, in company with Mr. von Harlessen and Mr. Giese, he had made a trial with the pneumatogen in the mine.† After the appliance had been in use for about 18 minutes, and as they were walking up a steep incline, it commenced to burn, and after great trouble he was able to prevent the flame from burning his clothes. It was found afterwards that heated peroxide of sodium and potassium had come into contact with an indiarubber ring, and caused it to take fire.

* *Trans. Inst. M. E.*, 1906, vol. xxxii., page 51.
† *Glückauf*, 1907, vol. xliii., page 524.

Mr. L. H. HODGSON said that the pneumatogen had been tried by Mr. W. E. Garforth in the Altofts-colliery experimental gallery with good results, but he thought that appliances of this kind would only be generally adopted in Great Britain when they were enforced by law.

Mr. R. CREMER (Leeds) wrote that Mr. von Harlessen, who was present at the incident, stated that the occurrence was due to an indiarubber jointing ring used in the pneumatogen at Gneisenau colliery; and that, in order to prevent such incidents, the indiarubber jointing material had been replaced by asbestos.

DISCUSSION OF MR. E. S. WOOD'S PAPER ON "SINKING THROUGH MAGNESIAN LIMESTONE AND YELLOW SAND BY THE FREEZING-PROCESS AT DAWDON COLLIERY, NEAR SEAHAM HARBOUR, COUNTY DURHAM."*

Mr. E. S. WOOD said that during the previous discussion a question was asked about the lowest temperatures that had been observed for freezing shafts, and why temperatures down to −34·4° Cent. (−30° Fahr.) were not used. He asked the contractors to give their experience in the matter, and they stated that many experiments were carried out in Holland to produce lower temperatures in the freezing-tubes by the direct expansion of anhydrous ammonia or carbonic acid. Temperatures of −18° to −21° Cent. (−0·4° to −5·8° Fahr.) were adopted in order to keep the freezing-tubes sound, because long experience had shown that with lower temperatures the freezing-tubes in many instances were broken. In one case, the temperature of the brine was lowered to −30° Cent. (−22° Fahr.) because running water was circulating in the strata round the freezing-tubes; the water was frozen, but a high percentage of the pipes were broken. The plant used at Dawdon was capable of working at much lower temperatures, but it was advisable not to do this in order to save the freezing-tubes from being broken.

Mr. F. COULSON (Durham) said that the variation of the water in the pit as compared with the tides seemed somewhat remark-

* *Trans. Inst. M. E.*, 1906, vol. xxxii., page 551; and vol. xxxiii., page 197.

able, and perhaps Mr. Wood could give some theory to account for it. Did the water in the pit rise in exact proportion to the tide, or was there any difference in the speed of rising? They found that, with tides varying from 14 to 17 feet, the water in the pit only varied about 4 inches. He would like to know, if possible, how this variation of rise and fall in the water varied with the rise and fall of the barometer, if that had been observed. It seemed to him that the attraction that made the tides might have some influence on the large mass of water that was located in the Magnesian Limestone? It seemed curious that the rise and fall of the water in the shaft was the same before the sand-feeders were tapped, and that the sand-feeders rose to a level 4 feet higher than the Magnesian Limestone feeders. He would be glad to know the cause of this.

Mr. R. Sutcliffe (Barnsley) asked whether the rising water in the shaft might not be retarded by the inlet through the sand. If the spaces through which the water flowed were very contracted, it could not enter in anything like the proportion of the movement of the tides. Thus, 8 inches in 17 feet represented 1 in 25; and if the time when the tide was in did not permit of more water getting into the pit during that time, it could not rise so high. With respect to the attraction of the moon or sun causing the rise of water in the strata of the earth, the rise of the tide was almost enough to indicate that this was not so. There was not a tidal variation of 17 feet out at sea, but part of the 17 feet would be caused by the land-resistance, causing an excessive rise through the momentum of the water set in motion by the tides, and the amount of water getting into the shaft would depend on the openings in the stone to admit it. He did not see how the attraction of the sun or moon would affect the rise of the water, without affecting the barometer much more, which it had not done.

Mr. M. Walton Brown said it occurred to him that the variation was not altogether due to the tide, but might be due to a variation of the hydraulic gradient, caused by the water in the strata being dammed up by the rising tide, and being released by the falling tide. This would occur if the level of the water in the shaft corresponded with the level of low water.

Mr. F. Coulson said that the water in the shaft continued to rise for 3 hours after the turn of the tide, and it appeared to him that on the tide falling, the shaft being only a short distance from the sea, the water ought to start to fall again, but it did not do so. The highest rises of water in the shaft occurred with a low barometer. There was a well at Sunderland, some distance from the sea, where the level of the water in the sand, about 45 feet above sea-level, used to rise and fall 4 inches with the tides. It might be caused by tides backing the water, but he did not see how this could take place without stopping the outlet.

Mr. E. S. Wood said that the rise and fall of the water in the shaft was carefully recorded; and, as Mr. Coulson had pointed out, it was at its highest about 3 hours after the tide was at its height. It gradually followed the rise and fall of the tide. The saltness of the water, when they were pumping, seemed to indicate that some of the gullets were connected directly with the sea, and that would account for the tidal variations of level. The fact of the water rising above the previous water-level, on the bore-holes passing through the Magnesian Limestone into the sand, might be owing to the outcrop of the sand, at the surface inland, being at a higher level than the water in the Magnesian Limestone on the coast. In that case, there was a flow of water from the higher level inland towards the sea, and the outlet at the shaft would naturally cause the water from the sand and below the Marl Slates to rise.

The President (Mr. J. H. Merivale) said that the points raised in the discussion were interesting, and Mr. Coulson might find that the forces which originated the tides would necessarily tend to cause similar tides in the water contained in the earth's crust.

Mr. Richard Harle's paper on the "Treatment of Dust in Mines, Aboveground and Belowground" was read as follows:—

TREATMENT OF DUST IN MINES, ABOVEGROUND AND BELOWGROUND.*

By RICHARD HARLE.

The recent explosions in mines undoubtedly confirm the opinion that "where there is dust there is danger," they prove that newly-made dust can easily be ignited with explosive violence, and they show the danger of using naked lights in dusty mines.

It is admitted that dust-accumulations are derived from the tops of loaded tubs in transit out-bye, on meeting the intake air; by the running of empty tubs in-bye; and dust caused by screening aboveground finds its way into the mine, and is deposited on all timbers, pillarings, floors and other places on the main roads.

The writer has been continually reminded of the destructive effects of explosions, and has seen so much of the dangers of dust, that he has endeavoured, in respect equally of its removal, its prevention and watering, to improve and get rid of the danger by a new system of damping and spraying, at the places above and belowground, where it is made.

With the view of preventing accumulations, the writer has previously described a method of dealing with dust by automatically sprinkling the tops of loaded tubs, before leaving the in-bye stations.† That arrangement has been in use at Browney and South Brancepeth collieries for a number of years, and it has done much to prevent accumulations of dust on the road-ways, along which the coal is conveyed.

Another mode has recently been perfected to deal with the dust-danger aboveground and belowground: it can be applied at any place wherever fine water-spraying is required for damping or cooling; and, by its means, the damped dust is arrested and kept secure in the tubs during transit on the main roads from the in-bye landings to the shaft.

* Application for British patent, February 13th, 1907, No. 3,612.

† "Automatic Sprayer for Preventing Accumulations of Dust in Mines," by Mr. R. Harle, *Trans. Inst. M. E.*, 1899, vol. xviii., page 113.

The new arrangement provides wet zones of misty spray on the wagonways, traversed by the tubs; dampens both full and empty tubs, and moistens the dust so as to ensure its removal out of the pit; and the air, periodically saturated as it goes in-bye, deposits sufficient moisture to damp any other dust.

The distributors can be fixed to stand-pipes and applied to screens, coal-tipplers, coal-conveyers, coal-drawing shafts, or other places aboveground, to moisten the dust at any point where it arises, and to prevent it from getting into the mine.

The apparatus can be fixed at any intervening space on underground roadways, at junctions, at rope-offtakes, and where one haulage-road joins another, so as to isolate each district, and at or near the shafts or in-bye stations. The water is delivered at a high pressure, and is pulverized by the action of the distributors, for the precipitation of dust.

The new apparatus works automatically, and can be applied to both main-and-tail-rope or endless-rope systems of haulage. The spraying continues during working hours, so long as the tubs are travelling, and ceases at the end of the shift, when no coal is in transit.

The arrangement consists of a small pump, about 2 inches in diameter and 6 inches stroke, with gearing and attachments, capable of delivering sufficient water, at a pressure of about 100 pounds per square inch, to a spray-pipe, $\frac{3}{4}$ inch in diameter, placed in the gallery, and fitted with nozzles and distributors to pulverize and distribute the water equally over the surrounding surfaces. The approximate quantity of water pulverized from each nozzle and distributor is about 1 quart per minute, under a pressure of 100 pounds per square inch; and it can be varied according to the pressure, and to the size of the hole in the nozzle.

On the roadways where coal is conveyed by main-and-tail-rope haulage (figs. 1, 2 and 3, plate ix.), the drum or friction-wheel, A, is actuated preferably by the movement of the tail-haulage rope, B, arranged by pulleys, C and D, to pass over or under the wheel, A, at a point near to the pump, G, gear-wheels, E and F, and water-tank, H. The water-pressure is controlled by a valve, J, on the delivery-pipe, K; and the water can be delivered at a pressure of 100 pounds per square inch (figs. 4, 5 and 6, plate ix.). The delivery pipe is fitted with nozzles, L,

arranged to produce a fine spray, both in-bye and out-bye. The wet zone can be extended to a length of 150 feet or more in either direction, by extending the spraying or outlet pipe.

The method of spraying where endless-rope haulage is in use is shown in figs. 7, 8 and 9 (plate ix.). In this case, a suitable length of rope or chain, A, is arranged on the tub-way, and carried round a drum or sheave, B. The apparatus is controlled and kept in motion by the tubs as they pass over the chain, thereby working the shafting and gearing in connection with the pump, C, and keeps a continuous spray in the gallery as the tubs pass along. Water is stored in the tank, D; and forced by the pump, C, through the pipe, E, and regulating-valve, F, to the pipe, G, fitted with nozzles, H, producing a misty spray, both in-bye and out-bye (figs. 10, 11 and 12, plate ix.). The wet zone can be extended to a length of 150 feet or more in either direction, by lengthening the spray or outlet pipe.

The author has designed two patterns of nozzles and water distributors for attachment to the pipes of the automatic water-spraying apparatus. In the first design, the nozzle, A, made of pipe $\frac{3}{4}$ inch in diameter, is screwed into the water-supply pipe; B, is a barrel or drum, fitted with blades or vanes, C, and carried by the bridle or supporting straps, D, attached to the nozzle by the screw or rivet, E (figs. 13 and 14, plate ix.) The second design is similar in every respect, except that the drum or barrel, B, is fitted with a diverting ring, F, which materially assists in the formation of the water-spray (figs. 15 and 16, plate ix.). The dimensions of the nozzle and of the distributor may be varied to suit any diameter of pipe or flow of water.

The working of the machines show the following advantages:—

(1) Sprayed and well-watered zones, over long distances, are produced at any suitable place in the galleries or main roads.

(2) Each district can be isolated; and, in case of an explosion of gas, damage to roadways and air-crossings will be prevented, the loss of life will be greatly minimized, and the entry of fresh air into the mine will be facilitated.

(3) The dust, kept moist and secure in its transit in tubs on the wagonways, is carried out of the mine, just as in damp mines, where no trace of dust is found.

(4) There is no excessive watering or wetting of coal.

(5) It obviates the danger of dust accumulating in the galleries, and prevents it from being carried in-bye to the face-workings.

(6) The distributors prevent, when placed aboveground, the removal of dust, which is found at screens and other places aboveground, and prevent it from moving about the shaft and passing down the pit.

(7) There is no waste of coal or dust in screening, or in conveying it to the coke-ovens; and explosions are prevented in coke-ovens and other places aboveground.

(8) The cost of upkeep and supervision is almost *nil*, and the system will save labour and cleaning of roads.

(9) It requires little, if any, extra space to fit it on the main roads.

(10) The coal-dust is arrested at the source, and absolute safety is afforded against sweeping explosions.

The PRESIDENT (Mr. J. H. Merivale) said that one of the most important problems in connection with the question of watering was the effect of damping the roads, as it might cause heaving and other injury in the mine. It seemed to him that the arrangement proposed by Mr. Harle would very largely overcome the difficulties, as, instead of damping the floor, it would simply damp the coal on the top of the tubs. The greater part, probably the whole, of the dust distributed on haulage-roads must necessarily come from the sets of tubs, or be blown down the shaft from the screens; and, by damping the coal on the sets of tubs, the dust would be prevented from accumulating on the ground and causing those difficulties, which arose from the use of water on haulage-roads.

Mr. E. S. WOOD (Dawdon colliery) endorsed what had been said by the President about the use of water-sprays in mines, as, in some mines in the county of Durham especially, undue watering of haulage-roads would materially affect both the roofs and sides; but, at the same time, watering seemed to be a step in the right direction. There could be no doubt that coal-dust was a source of great danger in coal-mines. The danger might

be reduced by providing proper tubs, with absolutely tight bottoms, so that coal-dust could not get out on to the haulage-roads, upon which the tubs were travelling. And further, the provision of distinct and separate wet zones in the different districts might, in the case of an explosion, absolutely prevent the explosion from being carried over the wet zone. The apparatus described in Mr. Harle's paper might be adapted to a certain extent to making such a zone immediately under the water-spray. A distance of 450 to 600 feet in the vicinity of the water-spray might be arched and made absolutely wet without damaging the floor of the seam and causing heaving, and it would obviate the probability of an explosion passing beyond that wetted area. These watering arrangements could be placed at the different engine-landings, and at some collieries they might be placed near the working-places. He suggested further that portions of the haulage-roads should be converted into absolutely wet zones.

Mr. C. C. Leach (Seghill colliery) said that he had sent samples of dust from haulage-roads for analysis, and he was asked why coal-dust had not been sent. This dust had been actually collected by himself from the roofs and sides of haulage-roads. He thought that it chiefly consisted of clay and shale, with a little coal-dust. He thought that water-spraying could be done, without special machinery; and water under pressure from the surface would make a more efficient spray than would be produced by a small pump. He did not quite agree with Mr. Wood that haulage-roads could be sprayed without injury. Watering would be chiefly required, in wide places, at the junctions of haulage-roads, and the effects would sometimes be very injurious.

Mr. T. C. Futers (Newcastle-upon-Tyne) said that Mr. Harle claimed that his arrangement would prevent the accumulation of dust on the heapstead. The apparatus would simply spray the top of each tub as it passed underneath it, and consequently he did not see how the coal inside the tub would be sufficiently damped so as to prevent the dust from rising, especially on the jigging-screens, where it would cloud the air and finally pass down the shaft.

Mr. C. H. Steavenson (Redheugh colliery) said that the arrangement was very ingenious, and the members were indebted

to Mr. Harle for bringing it to their notice; but he did not think that watering was the solution of the difficulty. He had found that the watering of roadways had a most injurious effect upon them; and, although that method suited some collieries, it was necessary to discover some means of removing the dust without watering it. It was possible that it might be enacted by Parliament that dust should be removed by brushing; but it occurred to him that it might be possible to remove dust from mines by means of suction-machines, similar to those used for cleaning carpets.

Mr. C. C. Leach (Seghill colliery) asked what was the cost of cleaning a square yard of carpet, and then only a few ounces of dust would be removed.

Mr. T. C. Futers said that such an arrangement had already been successfully applied to a screening-plant: a series of suction-pipes were applied to the jigging-screens, and all the dust was withdrawn from the screens and so prevented from going down the pit.

Mr. R. Sutcliffe (Barnsley) said that the removal of dust by brushing in a strong current of air would result in the dust being carried in large quantities into the working-places, and that would be increasing the danger.

Mr. F. Coulson (Durham) said that if the water-spray was used in a length of haulage-road, arched with brickwork, so as to prevent crushing owing to the action of the water, and the space kept damp, it would stop any coal-dust explosion; but a severe gas explosion would be carried through any moderate length of damp ground. In any case, a wet zone would not prevent the after-damp from passing from the vicinity of the actual explosion into other districts. He suggested that tub-grease might render coal-dust more explosive, and pointed out that on an ordinary haulage-road hundreds of tons of tub-grease were used and ground and mixed with the coal-dust. He moved a vote of thanks to Mr. Harle for his interesting paper.

Mr. C. C. Leach seconded the resolution, which was cordially adopted.

Mr. R. HARLE, replying to the discussion, wrote that the sprayers were being efficiently used at the collieries under his charge, and it was found that no injury was done to the roadways by the dewy spraying. No walling or arching was required in the dustless zone. His best reply to all other questions and criticism on the performance of the invention would be by a practical demonstration of the working of the apparatus; and he would be very pleased to show it in use to any of the members.

THE SOUTH STAFFORDSHIRE AND WARWICKSHIRE INSTITUTE OF MINING ENGINEERS.

GENERAL MEETING,
HELD AT THE UNIVERSITY, BIRMINGHAM, JUNE 4TH, 1907.

MR. F. A. GRAYSTON, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting and of Council Meetings were read and confirmed.

The following gentlemen were elected:—

ASSOCIATE MEMBER—

Mr. H. SHARROCK HIGGINBOTTOM, Colliery Proprietor, African House, Liverpool.

STUDENTS—

Mr. VICTOR HOLMES MCNAUGHTEN BARRETT, Etruria Vicarage, Stoke-upon-Trent.

Mr. G. BAILLIE HILL, Gillott Road, Edgbaston, Birmingham.

DISCUSSION OF PROF. C. LAPWORTH'S PAPER ON "THE HIDDEN COAL-FIELDS OF THE MIDLANDS."*

The PRESIDENT (Mr. F. A. Grayston) remarked that Prof. Lapworth stated that "all the visible coal-fields [of the Midlands] are simply the exposed coal-bearing portions of what once was a continuous sheet of Carboniferous strata. . . . afterwards covered by a similarly continuous sheet of red Triassic rocks." He confessed that he was unable to reconcile this theory with the fact that the Carboniferous strata were frequently found to be unconformable with the overlying Triassic rocks: the latter, in Warwickshire, having generally only a slight inclination. It was true that Prof. Lapworth further stated that although this view was "adequate enough as a working generaliza-

* *Trans. Inst. M. E.*, 1907, vol. xxxiii., page 26.

tion, it is insufficient if the details be examined," and mentioned that there were large areas, like some near Charnwood, where "the Coal-measure sheet was swept off before the Triassic sheet was laid down;"* and later, he stated that in some districts the Coal-measures had been subjected to distortion and subsequent denudation before the Triassic rocks were deposited.†

It appeared desirable in considering the question of the hidden coal-fields that all information possible should be obtained to assist in forming an opinion as to the condition of the Coal-measures below the Triassic rocks. The late Sir Andrew C. Ramsay said, referring to the basin-shaped form of the Coal-measures, "the reason of this is that the Carboniferous strata were disturbed and thrown into anticlinal and synclinal folds, before the beginning of Permian and New Red Sandstone times."‡ Sir Charles Lyell considered that the amount of volcanic energy was great at certain epochs of the Carboniferous age; and that enormous curving and dislocation of the Carboniferous rocks and great denudation of their exposed surfaces occurred before the deposit of the Permian rocks.§ He (Mr. Grayston), however, believed that Prof. Lapworth's researches prevented his going as far as the above-named authorities on the question of the disturbance of the Carboniferous rocks prior to the Permian and Triassic periods, at all events, so far as the Midland coal-fields were concerned. He (Mr. Grayston) assumed that the Birmingham basin, referred to by Prof. Lapworth, formed one of the troughs described at the beginning of the paper. He, therefore, asked Prof. Lapworth, whether he could give any reason why the boring at Packington, which was fairly centrally situated in the basin, showed a much less thickness of red rock than that at Streetly, which was nearer to the edge of the basin and within 2½ miles of the eastern boundary of the South Staffordshire coal-field.

It was also stated that "judging from the manner in which the coal-seams thin away towards Wyken and Craven, it can hardly be expected that they will extend in workable thickness

* *Trans. Inst. M. E.*, 1907, vol. xxxiii., page 27.

† *Ibid.*, page 35.

‡ *The Physical Geology and Geography of Great Britain*, by Prof. A. C. Ramsay, third edition, 1872, page 301.

§ *The Student's Elements of Geology*, by Sir Charles Lyell, Bart., third edition, 1878, page 388.

far south of the latitude of Coventry."* He would be glad to know Prof. Lapworth's reasons for concluding that the Coal-measures would become less productive to the south of Coventry, because the coal at Wyken colliery was thicker than at other collieries in that district.† He (Mr. Grayston) did not take into consideration the thickness of the coal-seams below the Slate coal-seam, as they were not generally proved or worked in that district. The actual thickness of coal at Wyken colliery (section No. 5), from the bottom of the Slate coal-seam to the top of the Two-yards coal-seam was 26 feet, exclusive of 8 feet of ground occupied by partings.‡ At Hawkesbury colliery (section No. 10), the thickness of the same coal-seams was 24 feet 8 inches, exclusive of partings; at Hawkesbury colliery (section No. 13), the thickness was 21 feet 6 inches under the same condition; and at Bedworth colliery (section No. 12), 22 feet.§

It was also stated that "the productive measures are perhaps in their greatest force along a line drawn across the basin from Aldridge towards Tamworth."‖ Possibly that was so, but he (Mr. Grayston) suggested that the Thick coal-seam of Staffordshire, which he considered to be identical with the Two-yards and the Slate coal-seams and the intervening coal-seams of Warwickshire, would probably be found in a more or less direct line from Sandwell Park to Hawkesbury, subject, of course, to the possibility of disturbance and denudation.

Mr. T. H. Bailey (Birmingham) said that, in 1865, his father, Mr. S. Bailey, instructed by the Earl of Dartmouth, sank a bore-hole, near Newton Road railway-station, over the eastern boundary fault of the South Staffordshire coal-field; and a trial-shaft passed through 40 feet of coal, evidently the upturned coal-seams forming the Thick coal of South Staffordshire. From his studies of the district he had little doubt that the Thick coal-seam extended from Sandwell Park in the South Staffordshire coal-field to Hawkesbury in the Warwickshire coal-field. The occurrence of *Spirorbis*-limestone being an indication of

* *Trans. Inst. M. E.*, 1907, vol. xxxiii., page 44.

† "Vertical Sections of the Warwickshire Coal-field," *Geological Survey of Great Britain, Vertical Sections*, Sheet No. 21, 1857.

‡ *Ibid.* § *Ibid.*

‖ *Trans. Inst. M. E.*, 1907, vol. xxxiii., page 45.

underlying Coal-measures, he asked whether there were great variations of depth between the *Spirorbis*-limestone and the coals of the South Staffordshire Thick coal-seam.

Mr. ALEXANDER SMITH (Birmingham) said that Mr. F. A. Grayston's "President's address,"* dealing with the Warwickshire coal-field, might be discussed with Prof. Lapworth's paper. He could not help being impressed by the accuracy of the geological surveys of the South Staffordshire coal-field by Prof. J. Beete Jukes,† and the Warwickshire coal-field by Mr. H. H. Howell,‡ and their memoirs were still serviceable and indispensable to mining engineers at the present day.

A remarkable section of coal-seams had been proved in the Lower Coal-measures at the Tunnel pits of the Haunchwood colliery; and appeared to form the bottom of the basin at that part of the Warwickshire coal-field. The Coal-measures at Arley colliery rose rapidly westward towards the great north-and-south fault.§ In the bore-hole at Packington, the coal-seams occurred at the depth of 1,800 feet (nearly double that at Arley, 990 feet), and nearer the north-and-south fault, yet there was no evidence that the coal-seams were rising towards the surface. He confirmed the President's (Mr. Grayston's) statement as to the thickness of the coal-seams at Wyken and Craven collieries; it certainly proved that the seams were not thinning out at Coventry; and it was favourable to their continuance southward for a longer distance than Prof. Lapworth anticipated.

Mr. DANIEL JONES (Shifnal) said that Prof. Lapworth had done great service in laying before the members a survey of the more or less associated and kindred coal-fields of the Midlands. For want of opportunity in making a wide study, mining engineers were prone to generalize from insufficient data, and to draw conclusions from observations gleaned in their own coal-field. Now, Prof. Lapworth had spread before them a Carboniferous tract with its superincumbent strata removed, and proved

* *Trans. Inst. M. E.*, 1906, vol. xxxii., page 312 and plate xiv.

† "On the Geology of the South Staffordshire Coal-field," by Prof. J. Beete Jukes, *Museum of Practical Geology and Geological Survey: Records of the School of Mines and of Science applied to the Arts*, 1853, vol. i., page 149.

‡ *Memoirs of the Geological Survey of Great Britain and of the Museum of Practical Geology: The Geology of the Warwickshire Coal-field and the Permian Rocks and Trias of the Surrounding District*, by Mr. H. H. Howell, 1859.

§ *Trans. Inst. M. E.*, 1906, vol. xxxii., page 316.

that the coal-fields generally spoken of as separate formed one homogeneous whole. The contents of this area could only be approximately determined; and the contour of the pre-Carboniferous basin, and the effects of denudation at varying periods, could not be ascertained by theoretical reasoning.

The Symon fault of the Shropshire coal-field was an illustration of extensive denudation. It was traceable from the Woodhouse pits of the Lilleshall company by Stirchley and the Hem pits, and had shorn off the whole of the southern end of the Coalbrookdale coal-field. Southwards, in the Forest of Wyre coal-field, Upper Coal-measures only were found resting on an Old Red Sandstone base; until at Billingsley and Highley a considerable area of the productive coal-seams of the lower part of the Coalbrookdale series occurred. Outliers of similar productive coal-seams occurred at Shirlot, and in the Brown Clee and the Titterstone Clee coal-fields. It was evident that, as originally laid down, the productive coal-seams extended far away westward over the Old Red Sandstone base. From his (Mr. Jones') researches, it would appear that this particular denudation must have taken place at the close of the formation of the Middle Coal-measures and before the Upper Coal-measures were laid down; but no one could determine how far it had extended eastward in denuding the productive coal-seams. It was even possible that the Coalbrookdale coal-field was only an island of Coal-measures similar to those of Shirlot, Highley and the Clee Hills. The boring at Claverley did not prove productive coal-seams, but that might have been due to two causes: (1) The high level of the original Silurian base or (2) the denudation of the older Coal-measures. There could be no doubt that productive coal-seams did exist between the Baggeridge pits and some undetermined point westward. This illustration of denudation supported the wise remarks made by Prof. Lapworth by way of caution to mining engineers, and he could speak from his own experience in three different cases where considerable expenditure had been incurred in boring with futile results. The boreholes were first made and the geologist was consulted afterwards, thus putting the cart before the horse.

Prof. R. A. S. Redmayne (Birmingham), referring to the statement made by Prof. Lapworth, on the authority of the Royal

Coal Commission, that the limit at which coal could be profitably worked was 4,000 feet, said that recent developments in Belgium tended to disprove this, as some collieries were already very near the said limit and were being extensively and profitably worked. The greatest difficulty in the way of deep coal-mining was the heat-increment, but he thought that it did not say much for science if, in the near future, cheap and practicable means were not discovered to minimize that difficulty. Furthermore, the variation in the rate of increase in the temperature in point of depth was very great as between district and district, and so far no satisfactory explanation for this difference was forthcoming. He (Prof. Redmayne) remarked that at the Tamarack copper-mine, in Michigan, U.S.A., a depth of 5,100 feet had been attained, and no difficulty was experienced from the temperature, which was but slightly increased. He (Prof. Redmayne) asked Prof. Lapworth how far, in his opinion, workable coal extended in the direction of Frankly Beeches, near Halesowen. Mr. G. H. Timmis' Witley colliery, not shown on the map of the Geological Survey, proved the existence of workable coal further than was originally expected; but, at the same time, it showed, owing to the rise of the measures in the direction mentioned, that the limit of workable coal had been very nearly reached in this part of the coal-field.

Mr. J. C. Forrest (Wolverhampton) said that the faults on the west of the Cannock-Chase coal-field were not correctly indicated on the maps of the Geological Survey. The western fault, north of Wolverhampton, had not, as was once supposed, a big downthrow; and south of Wolverhampton, it had not been proved, but the indications seemed to show that there would be a big downthrow beyond the Baggeridge area, as the fault seemed to increase in size going southward. In an area on the western side of Cannock Chase, there was sometimes an upthrow fault, and then, of course, a much larger downthrow fault. At other places, there was a very heavy dip in the measures, all to the westward, and all leading down to what was no doubt the original level of the coal-field. These indications showed that the Cannock Chase coal-field and that of South Staffordshire were formerly raised from a lower level, and, in consequence, the edges on the east and west sides, where the break took

place, were not necessarily clean cut, but rather the reverse. There would be areas, as had been proved at Baggeridge on one side and at Pelsall and Walsall Wood on the other, where the upheaval from the lower level had not raised the coal-seams to the ordinary level of the surrounding country. But the fact remained that to reach workable coal-seams on the west or on the east, the level at which the highest workable coal-seam would be found under the New Red Sandstone would be about 2,000 feet below sea-level.

In a general way he asked Prof. Lapworth, if east-and-west lines were drawn across the coal-field, whether the coal-seams found along such lines were, as a rule, of much the same thickness and quality as they were found in the centre, taking that centre either in the South Staffordshire coal-field or in Cannock Chase as the case might be. For instance, taking a line from Baggeridge to Sandwell Park, one would expect that the same seams would be found to the west of Baggeridge as to the east of Sandwell Park, allowing, of course, for variations caused by distance and by what had been proved, say, on the west in the Highley or Shropshire coal-fields and on the east in Warwickshire, on the same east-and-west line of section. Similarly also, on drawing an east-and-west line across the centre of the Cannock Chase coal-field, the coal-seams to the west would be much the same, allowing, similarly, for the change already proved in the coal-seams worked in Coalbrookdale and district, and on the east by the seams proved along the same east-and-west line in Warwickshire. He thought, also, that it would be admitted that the coal-seams were more in number and of greater thickness, altogether, in the north than they were in the south, where, eventually, they died out. In the west, a very uncertain and large barren area appeared to extend to the east of the Shropshire coal-field, and he suggested that this barren area, or its cause, extended southward on the east side of the Highley coal-field.

North of the Cannock Chase coal-field, and between it and the North Staffordshire coal-field, there was a very uncertain area which carried with it many conditions like the area lying eastward of the Shropshire coal-field. He asked Prof. Lapworth whether he had found, under the Coal-measures in any of the coal-fields, beds of red rocks which yielded considerable bodies of brackish water.

Mr. GEORGE M. COCKIN (Rugeley) asked Prof. Lapworth whether recent geological evidence proved that rocks, older than the Coal-measures, cropped out under the New Red rocks in the northern parts of the basin lying between the northern end of the Cannock Chase coal-field and the Leicestershire coal-field. Prof. Lapworth said that *Spirorbis*-limestone bands were characteristic of the Keele series and the Upper Coal-measures; but Mr. J. T. Stobbs had discovered them in true Coal-measures as low down as the Bowling Alley coal-seam in North Staffordshire, and he (Mr. Cockin) had recently been able to locate a well-defined band of *Spirorbis*-limestone in the Cannock Chase Coal-measures, near the Main Hard or Old Park coal-seam.*

Mr. S. F. SOPWITH (Cannock Chase) said that Prof. Lapworth spoke of the probability of the productive Coal-measures of the Cannock Chase district pinching out altogether, beneath the Red rock covering, in a north-easterly direction; and that the productive Coal-measures were absent also under the Red rocks in the northern part of the Birmingham basin. Consequently a large part of the Mid-Staffordshire basin, lying to the eastward, would be barren of productive Coal-measures. He asked Prof. Lapworth whether this inference was correct, and whether any theories had been advanced as to the probable limits of the Coal-measures in this basin.

Prof. C. LAPWORTH said that the President (Mr. Grayston) had with great judgment addressed himself to the most vital points of his paper. If, considered as a whole, the Carboniferous rock-sheet did not, as the newer generalization implied, share in the fold-arches and fold-basins of the Triassic rock-sheet considered as a whole, then it was idle to expect that in these great basins there would be found more or less continuous hidden coal-fields, extending from one visible coal-field to another. And further, as formerly suggested by some authorities, if the Carboniferous rock-sheet had been finally folded and denuded before Triassic time, the newer generalization that Carboniferous and Triassic rock-sheets were folded in combination, appeared to be in conflict with the known facts. It might be replied that this

* "On the Occurrence of Limestone of the Lower Carboniferous Series in the Cannock Chase Portion of the South Staffordshire Coal-field," by Mr. George Marmaduke Cockin, *The Quarterly Journal of the Geological Society of London*, 1906, vol. lxii., page 523.

conflict was only in appearance. All these views were natural and harmonious enough if considered as summarizing parts of the whole truth, and as stages in the growth of knowledge. The earlier generalization of Sir Andrew Ramsay and Sir Charles Lyell that the Coal-measures were thrown into anticlinal and synclinal forms and denuded before the Permian rocks were deposited, still held good so far as the true Permian rocks of Yorkshire were concerned. But it had been disproved, with respect to the so-called Permian (or Keele beds) of the Midlands; for, as Mr. Walcot Gibson and others had shown, these followed at once conformably upon the underlying grey Coal-measures, of which, indeed, they formed merely the upward continuation. Again, the further generalization of the authorities, that so great a folding and denudation of the Carboniferous rocks took place before Triassic time, that the Carboniferous and Triassic sheets (spoken of collectively) were everywhere unconformable with respect to each other, parts of the former being absent altogether in some districts, had never been disputed. But during these pre-Triassic movements, it should be remembered that the Carboniferous rock-sheet was bent into synclines as well as anticlines, and in these synclines it would remain undenuded. And more, it must be remembered that the collective Carboniferous rock-sheet was originally so thick in the northern and central parts of the Midland area—the Coal-measures alone (including the so-called Permian) being from 3,000 to 8,000 feet thick—that only upon the highest anticlines and along the margins of the whole Midland basin, where the beds were at their thinnest, could it be reasonably argued that it was entirely denuded away. It was only natural, therefore, to infer that, with these exceptions and others of minor note, a more or less continuous Carboniferous rock-sheet still remained undenuded, upon which the Triassic sheet was in its turn deposited, the Triassic sheet not only extending over the collective undenuded mass of the Carboniferous sheet, but even over those areas from which the Carboniferous sediments had been denuded away.

But the folding movements did not close at the end of Carboniferous times. The Triassic sheet became eventually folded in its turn, and in its folds the underlying and still largely continuous surviving Carboniferous sheet must necessarily have taken part; and from this followed, quite naturally, the newer

generalization. From the arches thus finally formed in post-Triassic times, the Triassic rocks had since been swept off by denudation, and in these parts consequently, as a rule, occurred the visible coal-fields. And in the broad basins developed at the same time, and as yet undenuded, must, if anywhere, lie the hidden coal-fields which remained yet to be discovered.

Of course, this generalization only professed to be a guide on a broad and regional scale. There were movements in progress during the whole of Carboniferous times, probably over the whole of the collective Carboniferous area of which this Midland basin merely constituted a part. The Midland basin as a whole was then undergoing a general depression, so that the successive Carboniferous formations overlapped towards the southern margin. At the same time, however, the rate of depression seemed to have been much faster towards the central parts, for there the formations were thickest, and they all decreased in individual thickness southward from the centre. It was by no means unlikely, indeed it was highly probable, that this more central depression was correlated with a corresponding elevation and denudation towards and beyond the margin. And it was probable that even the floor of the great basin might have been in part locally warped and denuded, as in the case of the so-called Symon fault. But these were matters of theory and future discovery. At all events, the identity of the succession of the sub-formations throughout the Midland basin, and the persistence of their lithological characters forbade the assumption that any of the movements during Carboniferous times were of an importance sufficient to destroy the unity of the basin as a whole.

The Triassic period was also a period of movement and local denudation. The north-western half of the Midland Triassic area sank first under the waters, so that the successive Triassic formations overlapped each other in turn to the south-eastward, until finally nothing but the highest formation—the Keuper—was found. As the rate of depression was again most rapid to the north and north-west, all the Triassic formations thinned away to the south-eastward, so that the Keuper, about 2,000 feet thick in Cheshire, was reduced to less than 1,000 feet when it finally disappeared under the Lias of Warwickshire.

All these matters must be borne in mind when employing

the generalization of the post-Triassic folding and denudation, but they left its value as a general guide undisturbed.

As to the suggested difficulty respecting the borings at Packington and Streetly, it must be remembered that, in the Birmingham basin as elsewhere, the collective thickness of non-productive measures (including the Keele beds) increased to the northward, and also that the Birmingham basin was not a simple, but a compound basin, somewhat bent and broken by folds and faults. At Packington, not only was the floor of the basin locally raised from the west, but much of the southern Keele series was denuded; and at Streetly, not only were the rocks depressed deeply by the great downthrow of the eastern boundary-fault lying no great distance to the westward, but most of the more northern (and therefore thicker) Keele series was present, as well as the overlying Pebble-beds of the Trias.

It was pleasant to learn that in the southern part of the Warwickshire coal-field the coal-seams (at all events, those above the Slate coal-seam), did not actually thin away but only came closer together at the Wyken and Craven collieries, and that consequently there was a reasonable prospect that they might continue workable well to the south of the latitude of Coventry. Nevertheless, it must be carefully remembered how rapidly the corresponding coal-seams of South Staffordshire deteriorated and disappeared soon after they came together to the south, so that there was especial need for caution.

As respects the view that productive Coal-measures might be found in greatest force between Aldridge and Tamworth, this view accorded with the fact that the total thickness of the productive Coal-measures increased northward from the Thick-coal country into the country lying well north of the Bentley fault, while, to the north-east of this area, the coal-seams begin to rise towards the Permian anticline.

The discovery in 1865, referred to by Mr. Bailey, of the existence of the Thick coal-seam at Newton Road railway-station to the east of the boundary-fault was a most interesting point in the early history of the opening-out of the Birmingham basin. Since 1882, when the Carboniferous measures of East Warwickshire were found not to include the Millstone Grit as previously supposed, but to be made up of the same succession of formations as those of South Staffordshire, while the coal-seams had

already been proved to come together towards the south in the same manner, it had been acknowledged on all hands (by those who had carefully considered the matter) that the Thick coal-seam and its representatives probably extended more or less continuously under the Birmingham basin into the Hawkesbury district. But the exact parallelism of the coal-seams in the two coal-fields was still far from being established.

The behaviour of the coal-seams, referred to by Mr. Alexander Smith, at the Tunnel shaft, at Arley colliery, and at Packington was explained if it were borne in mind that there was an upthrow fault and a rise of the beds immediately west of Arley. Consequently, the coal-seams at the Tunnel pit lay in the bottom of the basin formed between this rise to the west and the wellknown natural rise of the outcrop to the east near Stockingford. The Packington bore-hole lay away in the area on the downthrow side of the Arley fault, and hence the greater depth of its coal-seams.

The well-known Symon fault, to which Mr. Daniel Jones referred, was doubtless, where it occurred typically in the Coalbrookdale coal-field, a denudation-phenomenon, probably preceded by folding movements, as Mr. W. J. Clarke had shown.* Mr. Jones had done good service in pointing out that the movement and denudation might have extended for some distance to the south-west and south, and possibly even below some of the Red ground of the Wolverhampton basin. But the theory that the productive Coal-measures and the underlying Carboniferous formations once extended to the Clee Hills and had been removed by denudation at the time of the formation of the Symon fault, although a fascinating one, was far from being as yet established. At all events, the Carboniferous measures of the Titterstone Clee coal-field were claimed by some to be not those of the type of the Midland basin, but those characteristic of the Southland basin, those of the South Wales and Bristol coal-fields.

The new facts as to the behaviour of the western boundary-fault, brought forward by Mr. J. C. Forrest, were valuable additions to knowledge. The line of the fault laid down upon

* "The Unconformity in the Coal-measures of the Shropshire Coal-field," by Mr. William James Clarke, *The Quarterly Journal of the Geological Society of London*, 1901, vol. lvii., page 86.

the old maps of the Geological Survey had long been acknowledged by some as not marking everywhere the main dislocation, which might in some areas lie very much farther to the west. There was much to be said for the view that the dislocation and its branches formed in some districts a compound series depressing the coal-seams to greater and greater depths.

Doubtless it was to be expected as the coal-seams of South Staffordshire varied in number and character, gradually as they were followed from south to north; that they would continue more or less unaltered in these respects as they were followed at right angles to this (or from east to west), not only over the visible coal-field but also into the hidden coal-fields on either side. But, when this generalization was employed, it should be checked by calling to mind the general form of the Midland Carboniferous basin considered as a whole, and it might be anticipated that, when followed under the Red ground outside the South Staffordshire coal-field, the lines of similarity would bend more and more northward, at all events in the Wolverhampton basin, in proportion as the distance from the visible coal-field increased.

The presence of saline waters in the Carboniferous and underlying series would form a good subject for a special paper.

The discovery by Mr. G. M. Cockin of a band of *Spirorbis*-limestone in the productive Coal-measures of Cannock Chase formed another link in the lengthening chain of evidence bearing upon the original continuity of the Coal-measures of North and South Staffordshire, and one looked forward with growing confidence to the time when the coal-seams and marine bands of the two districts would be more or less paralleled in detail. While it was doubtless true that *Spirorbis*-limestone bands occurred not only in the non-productive, but also in the productive Coal-measures, they were apparently much more prevalent in the latter than in the former. And as Mr. T. H. Bailey had suggested, some of the *Spirorbis*-bands of the non-productive Coal-measures where they overlaid the productive series, although the examples referred could not be asserted to be absolutely constant in position, yet they had nevertheless proved a valuable aid in the Southern Midlands in estimating the probable depth of the workable underlying coal-seams.

In reply to Mr. S. F. Sopwith and Mr. G. M. Cockin, it

might be pointed out that, where the Pennine anticline was overlapped by the Red rocks of the Stafford basin, from Cheadle to Derby, the Carboniferous rocks were denuded, even down to the level, locally, of the Mountain Limestone; and, almost on the opposite side of that part of the basin, on the north-east of the Leicestershire coal-field, the denudation extended down to the level of the Millstone Grit. Even if the denudation was not as great under all the Red ground of the basin lying between these two areas, the presence of undenuded Coal-measures in mass was, to say the least of it, doubtful. Again, the influence of the Pennine anticline was felt even in the north-eastern area of Cannock Chase, where the Millstone Grit laid at no great distance below the surface, a fact pointing in the same direction. Although east of that area, the great eastern boundary-fault might again bring down the productive Coal-measures for a certain distance under the Red rocks, the Carboniferous rocks would naturally retain their general rise towards the Pennine anticline, and a broad spread of barren ground might therefore be found under the Red rocks of what had been called the Melbourne-Derby ridge.

The downward workable limit of 4,000 feet, referred to by Prof. R. A. S. Redmayne, was not a limit set by geologists, but that accepted by the last two Royal Coal Commissions. It was pleasant to be assured that mining engineers had already exceeded it successfully and profitably, and that consequently all the buried coal-fields might in time be worked. In the meantime, however, Midland engineers could afford to be patient. Within the last thirty years, about 500 square miles of hidden coal-field had been added to the productive areas in Nottinghamshire within that depth, the extent of the Warwickshire coal-field had been doubled, and in the same way as the Birmingham basin was opened out more than thirty years ago, by the late Mr. Henry Johnson's successful sinking of the shaft at Sandwell Park, the Wolverhampton basin had now been opened out by Mr. John Hughes' successful sinking of shafts at Baggeridge Wood.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

EXCURSION MEETING,
HELD AT SUNDERLAND, JUNE 6TH, 1907.

C PIT, MONKWEARMOUTH.

The freezing method of sinking the new or C pit has been adopted, so as to avoid any chance of disturbing the A and B pits, at the adjoining Wearmouth Colliery, which have been in operation for seventy years. These pits are sunk to the Hutton seam, at a depth of 1,723 feet; and the new or C pit will be sunk to the Harvey seam, at a depth of 1,902 feet. The C pit, 18 feet in diameter, is now sunk to a depth of 117 feet; but sinking operations have been suspended until the strata are frozen. For this purpose, 28 holes, 360 feet deep, have been bored round the circumference of the shaft, in a circle, 28 feet in diameter—three boring-machines, three steam-winches, and three steam-pumps being employed. Boring commenced on October 8th, 1906, and was completed on March 15th, 1907: the total boring of 9,725 feet being thus completed in 128 days, or an average of 25 feet per day.

Hollow rods, 2 inches in diameter and in 16 feet lengths, were employed, the weight-rod being 16 cwts. The chisels varied from 7 inches to 12¼ inches in diameter, and weighed from ½ cwt. to 1½ cwts. The steam-pumps forced 4,000 gallons of water through each set of boring-rods per hour, the pressure at the pumps being 75 pounds per square inch. As an example of the speed of boring, one hole was bored 100 feet by means of chisels, 12¼ inches in diameter, and the hole was lined with tubes 11 inches in diameter; it was then bored 90 feet deeper with chisels 10¼ inches in diameter, and lined to this depth with tubes 9¼ inches in diameter; and the remaining 170 feet were bored with chisels 7¼ inches in diameter, and the full depth was lined with tubes 6¼ inches in diameter, the total time occupied being 10

days. Each freezing-pipe comprises an upper tube, 240 feet long and 5 inches in diameter; an expansion-piece; and the lower tube, 4 inches in diameter and 120 feet long: the double nipple being placed at a depth of 75 feet.* The central pipe, 1 inch in diameter, delivers the brine 3 feet above the bottom of the freezing-pipe.

The refrigerating agent is anhydrous ammonia, and the brine is a 28-per-cent. solution of chloride of magnesium. Freezing commenced on April 10th, 1907. On June 6th, 1907, the temperature of the brine entering the pit was 2° Fahr. (−16·6° Cent.), and returning from the pit, 9·5° Fahr. (−12·5° Cent.). The cooling water entered the condensers at a temperature of 54·5° Fahr. (12·5° Cent.), and left at 61·7° Fahr. (16·5° Cent.). The circulation of brine is about 150 gallons per minute, and the quantity of cooling water is approximately 200 gallons per minute. The pressure of the ammonia in the condensers is 9·8 atmospheres, and in the refrigerators, 0·6 atmosphere.

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* *Trans. Inst. M. E.*, 1906, vol. xxxii., page 576, plate xxviii., fig. 8.

MANCHESTER GEOLOGICAL AND MINING SOCIETY.

GENERAL MEETING,
HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER,
MARCH 12TH, 1907.

MR. CHARLES PILKINGTON, PRESIDENT, IN THE CHAIR.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. TOM STONE, Mining Engineer, The Collieries, Garswood, near Wigan.

Mr. PERCY HOUSTON SWANN WATSON, Mining Engineer, 11, Trafalgar Square, Ashton-under-Lyne.

ASSOCIATE—

Mr. JOHN GALLIFORD, Colliery Manager, 479, Edge Lane, Droylsden.

STUDENT—

Mr. H. HARGREAVES BOLTON, Jun., High Brake, Accrington.

DISCUSSION OF MR. W. E. GARFORTH'S PAPER ON "A NEW APPARATUS FOR RESCUE-WORK IN MINES."*

The PRESIDENT (Mr. Charles Pilkington) said that the committee, entrusted with the work of fitting up a station, near Tyldesley, for rescue-apparatus and for teaching men how to use it, would start operations at once, and he hoped that six months hence there would be a place connected with the collieries of the district, where mining engineers and others could see rescue-apparatus at work and be trained in its use, or to which they could send their men to be trained.

Mr. W. E. GARFORTH gave a demonstration of the working of the Weg apparatus. He would have preferred that the members had attended at Altofts to see the apparatus in use in

* *Trans. Inst. M. E.*, 1906, vol. xxxi., page 625; and vol. xxxiii., page 180.

the experimental gallery, under conditions which approximated as nearly as possible to those found in a mine after an explosion—as regarded damaged roadways, contracted passages and a noxious atmosphere. He had been engaged on the work of the life-saving apparatus for many years, and still considered that it could be improved. The supply of oxygen was sufficient for 2½ hours, if the wearer were undergoing exertion, or enough for 6 hours when the wearer was resting. The purifier contained about 2¼ pounds of caustic potash and caustic soda, which absorbed the carbon dioxide given off by the person wearing the apparatus. The apparatus had been made entirely at the colliery, but when it was put into the hands of a surgical-instrument maker he apprehended that the weight, at present 30 pounds, would be materially reduced. The apparatus did not interfere with the hearing of the wearer, and the goggles over the eyes could be removed (when advisable) without interfering with the other parts of the apparatus. As only a small portion of the head was covered, perspiration was as far as possible unchecked.

Mr. Joseph Dickinson said that had Mr. Garforth carried his history of rescue-appliances 13 years prior to Sir Henry T. De la Beche and Dr. Lyon Playfair's invention, it would have comprized one on a similar basis for which 50 guineas and a silver medal was presented by the Society of Arts and the Royal bounty of £100 by King George IV.* The inventor was Mr. John Roberts (of Upton-and-Roberts safety-lamp fame). The apparatus consisted of a mask, with goggles and inhaling arrangements through the interstices of a sponge immersed in varied saturated solutions of lime-water, chloride of lime, caustic soda, and sometimes pure water, according to the impurity likely to be met with. The expired air was not passed through the inhalator.

Personally, the only breathing-appliance used by himself (Mr. Dickinson) on many explorations in foul air was the 1846 bag of Glauber salts and lime. The mine was on fire, following an explosion in 1851, and Mr. Goldsworthy Gurney's treatment with the fumes from burning coke, salt, and sulphur had

* "Apparatus to enable Persons to breathe in Thick Smoke, or in Air loaded with Suffocating Vapours," by Mr. John Roberts, *Transactions of the Society of Arts*, 1825, vol. xliii., page 25 and plate i.; and *Report from the Select Committee on Accidents in Mines*, 1835, page 262.

failed to extinguish the conflagration. The bags with the mixture were used for some hours, most of the explorers being sick; and eventually the bags were discarded, and the fire was approached in the old-fashioned way.

Rescue-apparatus were now available of better form, and possibly some such might have saved some time; but the saving would probably have been less than some persons might suppose. On such occasions, when survivors might possibly be rescued or valuable property saved, advances were made which under ordinary circumstances would be inexcusable. Dormant side-accumulations of foul air were then passed by, and left for future clearance. Exploration also followed underneath smoke and gas to close a hole in a blown-out stopping, and close touch was kept with the advancing air-column. In front of this, among débris, it would often be imprudent for apparatus-men to advance far. The common tests for gas—elongated flame and blue cap for fire-damp, dulled flame or extinction for black-damp, sensitive creepings for after-damp and white-damp—did not delay much, and with practice and care were reliable. The good results occurring from the lessening number of fire-damp explosions were it seemed so diminishing opportunities for re-entering that special education was now suggested; consisting of the establishment of central training-stations with rescue-apparatus and a practising-gallery, which deserved favourable consideration.

Mr. W. E. Garforth pointed out that the apparatus would be considerably lightened if it were charged to last a man for only an hour. He asked Mr. Dickinson to say, from his unequalled experience in rescue-work, if at times he had not found it of the utmost advantage for a man to be able to get as soon as possible into a pit when an explosion had occurred in order to ascertain the state of affairs underground. He did not hesitate to say that five men, who had been trained in the gallery in the use of this apparatus, could go into the most noxious atmosphere, and give relief to men who might be suffering. He held that if they could only save one life, it was worth all the trouble that he had taken in perfecting the Weg apparatus. With this apparatus a man would also be able to travel a certain distance, in order to ascertain if any part of the mine was on fire. On the occasion of an explosion at Altofts colliery, a fortnight was lost

before they were able to reach a certain point where a fire was discovered; but with this apparatus they might have discovered the fire on the second day, instead of suffering great risks and anxiety actually incurred.

The PRESIDENT (Mr. Charles Pilkington) said that he was in favour of rescue-apparatus being provided, but there was a difficulty in the matter of weight. Thirty pounds was a great weight for a man to carry a long distance. As to the general utility of rescue-appliances, it had been stated that no lives were saved through their instrumentality after the Courrières explosion; but it must be remembered that there were no apparatus in the district at the time of the disaster.

Mr. JOHN GERRARD said that occasionally the need arose, in exploring mines after explosions and in connection with fires, to use all the appliances that science and experience had suggested: thus mice and birds, by reason of their greater susceptibility to carbon monoxide, gave early intimation of its presence. The statement that rescue-apparatus failed at the Courrières mines, he emphatically declared, was most unfair, as the rescue-apparatus had not a chance to save life. It was perfectly true that men came out of the pit alive after Mr. G. A. Meyer arrived at the Courrières collieries, but everybody at that time firmly believed that there was not a living man in the pit, and everybody acted on that assumption. He (Mr. Gerrard) thought that Mr. Garforth was deserving of all praise for his persistent efforts to perfect this apparatus. Fortunately, Lancashire had been spared disastrous explosions of recent years; but not infrequently trouble had arisen through fires which might much sooner have been extinguished, if such an apparatus as that which Mr. Garforth had designed had been available for use. Life also would have been saved. In connection with fires, there was, he was persuaded, a big field for the use of this kind of apparatus in Lancashire. He was hoping that before long they would have a rescue-station in Lancashire, where men could accustom themselves to the use of these appliances. He (Mr. Gerrard) raised the question of what could be done in the event of a man equipped for rescue-purposes passing through foul air to a place where the air was tolerable and finding men

alive there. Mr. G. A. Meyer had made a supplementary apparatus to bring out men in such cases. He moved that the best thanks of the members be given to Mr. Garforth.

Mr. JOHN GALLIFORD seconded the motion, which was cordially approved.

Mr. JOHN GALLIFORD read a paper on "A New Reflector for Safety-lamps." The reflector, made of aluminium, 5 inches in diameter, can be fitted, above or below the standards or poles protecting the glass of a Clanny type of safety-lamp, by means of a spring clip or a bayonet joint.

MANCHESTER GEOLOGICAL AND MINING SOCIETY.

GENERAL MEETING,
HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER,
APRIL 9TH, 1907.

MR. CHARLES PILKINGTON, PRESIDENT, IN THE CHAIR.

The following gentlemen were elected, having been previously nominated:—

MEMBER—
Mr. WILLIAM OLDFIELD, Mining Engineer, West View, Minsterley, Shropshire.

ASSOCIATE—
Mr. GEORGE REYNOLDS WYNNE, Hope Cottage, Tarvin Road, Chester.

Mr. W. H. COLEMAN read the following paper on "The Cook Calorimetric Bomb":—

THE COOK CALORIMETRIC BOMB.

By W. H. COLEMAN.

Introduction.—In bringing this new pattern of bomb calorimeter before your notice, it is necessary to preface the description with a few words on fuel-valuation.

This subject may be divided into three heads:—(1) Sampling the fuel; (2) determining its calorific value; and (3) comparing different fuels, so as to find out which will serve the purpose in hand most economically.

(1) *The Sample.*—The chief difficulty in the way of determining the calorific value of a fuel is the fact that it is not at all easy to obtain an average sample. Unless the sample is what it professes to be, that is, of the same composition as that of the whole bulk of the fuel under examination, it is useless to waste time and money in making elaborate calorimetric determinations. If the sample is to represent a seam of coal, several freshly hand-cut portions should be taken from different parts of the seam; taking care that a strip is cut from a fresh face from top to bottom of the seam and that it contains everything, whether coal or dross, that would be sent to the surface as coal, and nothing else.

If the sample represents a delivery of a particular quality of coal, then a truck or a cart-load should be selected at random from a number of freshly-filled trucks or carts. Special care should be taken that the loads are average ordinary loads, which have been filled for delivery, without any attempt to pick the quality. The whole load should be tipped, well mixed, and quartered down until a sample of about 1 hundredweight is obtained. Great care must be taken that this contains the right proportions of large, small and fine coal. The sample should then be either put through a stone-breaker, or ground roughly in a mortar-mill. It should then be again quartered, until a sample weighing 2 or 3 pounds is obtained. This must then be ground in a suitable mill to a moderately fine granular powder. It is necessary, when determining the moisture in a coal, to be sure that it is

not too finely ground, and it should be bottled at once. The sampling, grinding, etc., should be quickly done, so that the coal may not lose moisture.

(2) *The Calorific Value.*—Three ways offer themselves for determining the calorific value of a fuel:—(1) An ultimate analysis of the coal may be made, and its theoretical calorific value may be obtained by calculation. This method, though accurate, takes a considerable time and requires the services of an expert

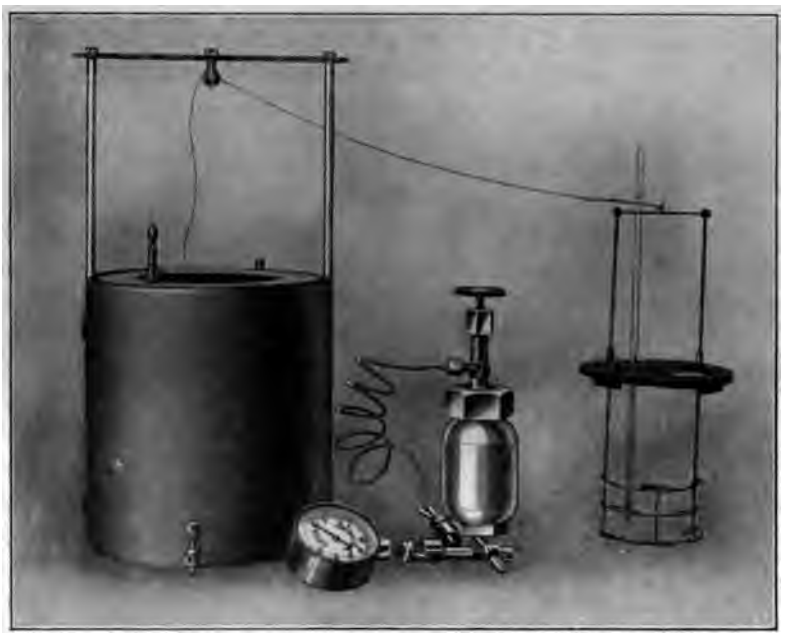

FIG. 1.—THE COOK CALORIMETRIC BOMB.

chemist. (2) The moisture, ash, volatile matter and fixed carbon may be estimated, and the calorific value calculated from one of the numerous formalæ given by different authorities. This method is simple, and can be carried out by an average intelligent laboratory-assistant; but the results, though useful in checking deliveries, the calorific value of which has been determined by the first method from a previous sample-delivery, are not sufficiently accurate to discriminate between several different qualities of coal. (3) The actual calorific value may be determined by means of a calorimeter.

In principle, all calorimeters depend upon burning a weighed quantity of coal and observing the rise in temperature imparted to a known quantity of water by the heat given out during the complete combustion of the fuel. Several forms of calorimeters have been proposed.

(*a*) *Lewis-Thompson Calorimeter.*—In this instrument, the weighed sample of coal is mixed with potassium chlorate or some other oxygen-carrying body and burnt in a bell-jar immersed in water contained in the calorimeter. The products of combustion bubble upwards through the water, to which they communicate their heat.

(*b*) *William-Thomson, Fischer and Darling Calorimeters.*—These calorimeters are all modifications of a similar principle. The coal is burnt in a crucible placed in a bell-jar immersed in water in the calorimeter. It is not mixed with any oxygen-carrying material, but a stream of oxygen is caused to pass into the bell-jar. The products of combustion escape, as in the first-mentioned apparatus. In the Fischer calorimeter, the gases pass through a special chamber.

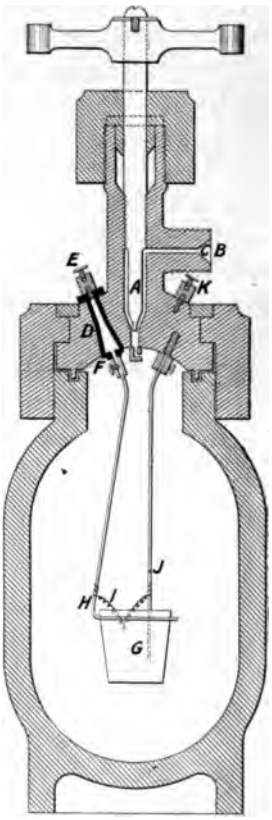

FIG. 2.—THE COOK BOMB. SCALE, 2 INCHES TO 1 INCH.

(*c*) *Parr Calorimeter.*—In this apparatus, the weighed coal is mixed with sodium peroxide, which serves to supply the oxygen necessary for combustion, and the caustic soda produced absorbs and combines with the carbon dioxide given off by the burning fuel. The mixture is placed in a closed metal chamber immersed in the water of the calorimeter, and ignited.

(*d*) *Berthelot-Mahler Bomb.*—In the new modification of this instrument (fig. 1), the weighed sample of coal is placed in a platinum crucible, G, which is then placed on the wire support-

ing ring, H (fig. 2). In order to ignite the coal, a fine platinum wire, I, is connected to the supporting ring, H, and to the other wire, J, depending from the cover. The latter, carrying the crucible, is gently lowered into the bomb and screwed up tightly. Oxygen, under pressure, is then admitted to the bomb until the gauge registers a pressure of about 21 atmospheres. The valve, A, is then shut, and the oxygen-cylinder is disconnected. The bomb is then carefully lowered into the copper calorimeter vessel, into which about 2 litres of water, slightly below the temperature of the room, is poured; and the wires of the battery are connected to the bomb, at E and K, the circuit being open. This vessel stands in another double-walled copper vessel filled with water at the room-temperature, and surrounded by felt to prevent loss or gain of heat from surrounding objects.

The agitator is set to work, and the rise in temperature of the water is observed; and, when this is constant, the circuit is closed, and the coal is burnt. The temperature of the water rises, and the maximum point is noted. Then the increase in the temperature of the water in Centigrade degrees, multiplied by the weight of the water and the water-equivalent of the apparatus, gives the number of calories evolved by the combustion of the weight of coal taken. If 1 gramme had been taken, then this number represents the calorific value in calories; and if not, then the figure is divided by the weight of coal taken. The calories multiplied by 1·8 give the British thermal units per pound of coal. The evaporative power of the fuel from and at 212° Fahr. is obtained by dividing the calorific value, expressed in British thermal units per pound by the number, 966, representing the latent heat of vaporization of water in Fahrenheit units. Several forms of this calorimeter have been proposed:—The original Mahler bomb; the Bryan-Donkin bomb; and the Cook-Berthelot-Mahler calorimetric bomb shown in figs. 1 and 2.

This latter form has several improvements, and has been found very satisfactory in use. The chief improvements are the gas-valve, A, and the gas-inlet, B. In older forms of the instrument, the gas entered at the top instead of at the side, and the valve had to be slightly loosened to disconnect the copper pressure-tube. Other minor advantages are the following:—The gas-inlet valve does not easily get out of order. The stirring arrangements are very simple. The connections have coned

joints, C, and do not require washers. The insulation, D, of the plug, E, is protected from injury by high temperature at the moment of explosion, by a quartz plate, F. Care must be taken that the apparatus is tight; and, to ensure this, the lead-washer should be examined to see that it is not burred.

Several points require a little attention: the coal should be dried at a temperature of about 110 Cent. (230° Fahr.); and should be finely powdered, and then made into briquettes with the small briquetting machine.

The water-equivalent of the apparatus is best found by determining the calorific value of pure cellulose (4,200 calories) or naphthaline (9,692 calories). A correction for cooling ought to be made for very accurate experiments.* If, however, the water-equivalent of the apparatus is determined by burning naphthaline, and such a quantity is used as to give about the same rise of temperature as the weight of coal taken, this correction may be neglected if the determination is only wanted to be within ½ or 1 per cent. of the truth.

It may also be advisable to correct the results for the nitric acid and sulphuric acid formed. This can be done by washing out the bomb after the experiment, and estimating the quantities of nitric acid and sulphuric acid formed.

The room, in which calorimeter-determinations are made, should have a temperature of about 60° Fahr., and the water should be about 2° Cent. (4° Fahr.) below the temperature of the room.

Of course, a calorimetric determination does not tell all there is to be known about the suitability of a coal for any particular purpose. The length of flame, the quality of the ash (whether easily fusible or not), and other factors must be taken into consideration; but, given several samples of coal, all of which are otherwise suitable for the intended use, the most economical coal can be selected by the calorimeter. If, from the result of the determination, the number of calories obtained for any given sum of money be calculated, it is easy to pick out the most economical fuel.

* This is made by observing the rate of the rise of temperature that takes place when the bomb is placed in the calorimeter and before the charge is fired, and also the rate of the fall of temperature during a similar period of time after the maximum temperature has been reached. From these observations, the loss by radiation during the experiment can be calculated and a correction applied.

At the present day, when every little detail has to be considered in order to make a profit, there is no doubt that the coal which can be guaranteed to give the best result for the money will find the readiest sale.

Anyone who is desirous of going further into the question of valuing fuel may refer to the excellent paper by Mr. J. B. C. Kershaw.*

The PRESIDENT (Mr. Charles Pilkington) thought that the instrument was very valuable, and suggested that, when a coal-owner wished to ascertain the true value of his coal-seam, or of a particular portion of a seam, samples taken from all points of the seam should be duly tested in the calorimeter by a competent person.

Mr. COLEMAN said that a sample of 7 or 8 pounds of coal should be sent, broken into nuts, and then the final grinding could be done quickly.

The PRESIDENT asked what allowance was made for ash.

Mr. COLEMAN said that no allowance was made for ash in the coal, as it would have the same influence in the calorimeter as in the furnace. The coal was burnt with pure oxygen. An electric current with a pressure of 12 to 20 volts would suffice to ignite the charge.

The PRESIDENT said that the calorimetric bomb was valuable, but he thought that it was more for use in the laboratory than at a colliery.

Mr. SYDNEY A. SMITH said that the calorific value of a coal could be ascertained by this instrument, but it did not indicate the value of the coal as a fuel suitable for a particular purpose; and much depended on the rate of combustion. In a recent case, there was a dispute about a shipment of coal. The calorific value was excellent, but it could not be burnt, except at a very slow rate, in the ordinary grates of water-tube boilers, without forced draught. In ascertaining the value of coal as fuel, that

* "Fuel Analysis for Steam Users," by Mr. J. B. C. Kershaw, *The Engineer*, 1906, vol. cii., pages 314 and 337.

point must be considered, because the value of a coal for a particular purpose depended on the rate of combustion. Some coals burnt rapidly, others burned slowly, and yet all might have the same calorific value.

Mr. COLEMAN admitted that even when the calorific value of a coal had been determined, the question as to the coal's suitability for a particular purpose was not settled. But given several coals, at different prices, that were suitable as regarded their burning qualities, the calorimetric bomb would indicate the one that produced the most heat for the least money. The question of ash was of the utmost importance in some cases.

A vote of thanks was accorded to Mr. Coleman for his interesting paper.

MANCHESTER GEOLOGICAL AND MINING SOCIETY.

GENERAL MEETING,
HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER,
MAY 14TH, 1907.

MR. CHARLES PILKINGTON, PRESIDENT, IN THE CHAIR.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. ALFRED ACKROYD, Elleralie, Victoria Crescent, Eccles.
Mr. HUGH FRANK TAYLOR, Mechanical Engineer, Sandy Croft, near Chester.
Mr. THOMAS WILLIAMS, Mining Engineer, 5, Westbourne Grove, Hexham.

Mr. Frederick J. Thompson read the following paper on "The Rock-salt Deposits at Preesall, Fleetwood, and the Mining Operations Therein":—

THE ROCK-SALT DEPOSITS AT PREESALL, FLEETWOOD, AND THE MINING OPERATIONS THEREIN.

By FREDK. J. THOMPSON.

Introduction.—This paper is divided into four parts, comprizing:—(1) The history and the geology of the rock-salt deposit at Preesall; (2) the method of sinking shafts for rock-salt; (3) the methods of mining rock-salt; and (4) a description of the Preesall salt-mine worked by the United Alkali Company, Limited.

(1) *History and Geology.*—The earliest record of any underground exploration, near Fleetwood, is that of a bore-hole, A (fig. 2, plate x.), put down by the Royal Engineers in 1860 in search of water for the troops then stationed at Fleetwood, the town at that time being entirely dependent on surface-wells for its water-supply. This bore-hole was carried to a depth of 559 feet, the whole of the distance being bored in Keuper marls—with the exception of a few feet, near the surface, in the usual surface-drift; but no water was found.

In 1872, the district on the Preesall side of the river Wyre was mapped out by a syndicate, with the intention of putting down twenty bore-holes in various places in search of iron-ore, as it was thought possible that such might exist on the south side of Morecambe bay, as well as at Barrow-in-Furness and other places on the north side (fig. 1, plate x.). The site of each of these twenty bore-holes was fixed, and some of them were bored simultaneously, but the only available records are those of Nos. 2, 8, 9 and 17 (fig. 2, plate x.). Rock-salt was struck in No. 2 bore-hole in 1872, and signs of rock-salt in two of the others; and there is no doubt that the discovery of rock-salt prevented the completion of the original design of twenty bore-holes.

In 1875, No. 17 bore-hole was put down about ¾ mile to the north-east of No. 2 bore-hole in which rock-salt had been struck,

and red sandstone was found at a depth of 45 feet from the surface. The boring was continued to a total depth of 564 feet from the surface, and indicated the existence of an enormous supply of fresh water. The map (fig. 1, plate x.) shows the relation of Fleetwood on the south side of Morecambe bay to Barrow-in-Furness on the north side. All previous geological surveys had indicated that the red-sandstone fault was 8 miles eastward of the site of No. 17 bore-hole, which had struck sandstone at Preesall. The author, in 1906, constructed a geological section running east-and-west through the rock-salt deposit, and the late Mr. C. E. de Rance expressed the opinion that it was substantially correct. A reproduction of this section is shown in fig. 3 (plate x.).

Nothing further was done in the development of the minerals, as the state of the salt-trade did not warrant such, except that in 1885, a shaft around No. 2 bore-hole, which had previously been sunk from the surface into the rock-head, was carried still lower into the rock-salt bed until the bottom was reached. This shaft indicated a total thickness of 340 feet of rock-salt stratified in several layers of very good and some of inferior rock-salt and marl.

The general theory amongst geologists as to the origin of the various rock-salt deposits found in this country is that, at some remote period in the world's history, considerable quantities of sea-water had, owing to changes in the earth's surface, been separated from the main body of the sea; and that solar evaporation concentrated such bodies of sea-water until salt was deposited. This flooding of the same area, happening again and again, would account for the deposits of marl and inferior rock-salt, which originally would be deposited as mud and salt. It is not the author's intention to express any opinion as to this theory; but it is obvious to anyone that salt could not have been in solution in sea-water, unless it had been dissolved from the solid mass in some previous formation.

Nothing was done in the way of serious development until 1889, when the reconstructed Fleetwood Salt Company, Limited, took over the undertaking, and the author was engaged by them to take charge of the development of the salt-beds. The old shaft previously mentioned was converted into a shaft for pumping brine, the small amount of natural brine found in it on the

rock-head being augmented by putting water down bore-holes, which were bored down to the rock-head at a short distance away from the shaft. Salt-works for the evaporation of the brine were erected on the Fleetwood side of the river Wyre and were connected to the brine-pumping station by a line of pipes, which were laid across the estuary of the Wyre (fig. 2, plate x.). It is not the author's intention to deal with the question of brine-pumping or salt-making, except to state that both operations have attained considerable proportions, especially since the erection of the Ammonia-soda works at Fleetwood by the United Alkali Company, Limited, who acquired the whole of the Fleetwood undertaking from the Fleetwood Salt Company, Limited, in 1890. It may be stated at this point that salt was required by the company as a raw material in the manufacture of various products involving the use of chlorine or sodium.

(2) *Sinking Shafts.*—In 1893, the United Alkali Company, Limited, decided to sink shafts for the purpose of mining rock-salt in a dry state, and they were commenced in that year. In sinking shafts for the purpose of mining rock-salt it is necessary to ensure the absolute exclusion of all water or moisture; as, rock-salt being extremely soluble, great havoc would be caused if water were allowed to enter any salt-mine. This must be effected, before the rock-salt bed is entered, in carrying down the shafts.

The first stratum passed through was the boulder-clay overlying the Keuper marls, and this was gone through by two timbered shafts, each 7½ feet square. A considerable amount of water was found in various places in sand-beds in the boulder-clay, besides enormous boulders, which occupied in some places the whole area of the shaft in sinking, and had to be blasted before they could be raised to the surface. The boulders were mainly of limestone, and many of them showed extraordinarily clear ice-markings of the glacial period.

The Keuper marls were reached with both shafts, which were continued until the marls were found in such a condition as to afford a safe foundation; at these points in each shaft, a brick-work foundation was built in with blue bricks and Portland cement; and from this foundation, iron tubbing was carried to the surface. This tubbing consisted of cast-iron socket-and-

spigot pipes, 6 feet in diameter. The space between the back of these tubes and the timbering of the shaft was filled with clay-puddle, and the absolute exclusion of the water was thus effected. The shafts were afterwards continued downwards through the Keuper marls to the rock-salt bed, and were stopped, for the time being, in a good bed of rock-salt, about 450 feet from the surface.

(3) *Mining.*—As an interval of 50 years had elapsed, prior to this, since any rock-salt mine had been opened out, the author had no previous personal experience to guide him as to the best method of opening out a mine in the shortest possible time. A rock-salt mine is different from most mines, owing to the fact that it does not consist of a series of passages or ways; but it is only one large excavation or cavern hewn out of the solid rock-salt, with solid masses of rock-salt left in at various places for the purpose of supporting the roof (fig. 4, plate x.). The usual way of opening out such a mine had been to commence enlarging the two shafts, around their bottoms, until they met and formed one excavation, and afterwards this operation was continued all around. This meant that for some time, owing to the smallness of the excavation, very few men could be put into the work, as blasting operations would render the presence of a large number of men undesirable, because of the danger.

It was ultimately decided to employ a compressed-air tunnelling-machine, to drive headings in various directions into the rock-salt at as rapid a rate as possible. This machine, supplied with air from a compressor stationed on the surface, drove headings 5½ feet in diameter at the rate of 360 feet per week. A heading was driven first from one shaft to the other in an easterly direction and continued a considerable distance in that direction, and afterwards a heading was driven in a westerly direction; and, while so driving in this westerly direction, men were put into the eastern heading to widen it out northward and southward. Another heading was driven by the machine in a northerly direction and other men put into the western heading, so that in a very short time there was a considerable area of excavation, 6 feet in height. The widening out of the headings was done by rotary undercutting machines, worked by compressed air, and these machines have been retained until this

day, four being now at work. The bed of rock-salt that is being mined is about 40 feet thick, and it dips in a north-westerly direction at the rate of 1 in 3½.

The rock-salt is mined by making a "roofing," A, 6 feet in height at the top of the bed; and the roof thereof afterwards forms the ceiling of the mine (fig. 5, plate x.). The roofing is done by machine-undercutting, in lengths of 105 feet—the distance between each pillar, the pillars being 60 feet square. Rock-salt is much harder to mine than coal, and an ordinary coal-undercutter will not touch it. The special undercutting machines made for this purpose, undercut to a depth of 2½ feet only.

The roofing lays bare the whole of the lower part of the bed, say, 34 feet thick, and this is worked by blasting from the face as in open quarry operations. Black gunpowder, in compressed cartridges, is used for the purpose of blasting all over the mine. The rock-salt, after blasting, is slid down the face to the floor of the mine where it is filled into hoppets, B, trammed to the shaft, and wound to the surface in the usual way (fig. 5, plate x.).

Members who have had any experience of the ordinary rotary undercutter, will no doubt be aware that, in undercutting from one face to another, the two ends of the cut cannot be touched, but have to be got out by other means, as the rotary undercutter will not start at, or finish right to the end of the cut. This necessitates getting out the two ends either in advance of the cut or after the cut has been made by the undercutter. In the case of rock-salt mines, it has been found easier to get out these ends after the long cut has been made; and, for this purpose, Ingersoll-Sergeant coal-cutting or punching machines are used. These machines are also used in other parts of the mine, where the range of cutting is so short that it will not pay to run the rotary undercutter.

It is in the direction of drilling holes for blasting that the most rapid strides have been made in advance of the old methods employed in Cheshire and elsewhere, and it has been the means of great economy over the original methods of drilling holes. The original method of drilling holes in rock-salt was by using a long bar of iron, steel-pointed at each end, as a jumping drill, worked by hand. By this means one man can drill a hole, 1½ inches in diameter and 5 feet deep, in about 45 minutes. The

author first introduced into salt-mines worm-drills, operated by ratchets, worked by hand, the Elliott drill being the most suitable for rock-salt mining owing to the fact that the pressure on the feed can be regulated by a friction-brake. This is especially necessary in rock-salt owing to its varying nature, several degrees of hardness being gone through in a single hole. Later, compressed-air motors were applied to the end of the feed-screw of these drills, the result being eminently satisfactory, and, at the present time, practically the whole of the drilling in the mine is done by means of drills driven by compressed-air motors. It is now quite easy for one man to put in a hole 1½ inches in diameter and 5 feet deep in 5 minutes, by means of one of these motor-driven drills.

(4) *Description of Mine and Plant.*—The total thickness of the rock-salt bed at the Preesall mines is approximately 380 feet; but, as stated previously, although homogeneous, it contains strata of varying quality and only a portion of it is mined. There are two levels in the Preesall salt-mine: the floor of the upper mine being about 470 feet from the surface, and that of the lower mine 900 feet. In opening these mines, a thickness of about 40 feet was mined in the upper level; but, some three years ago, the shafts were carried down to the bottom of the salt-bed, and it was found that a thickness of about 22 feet of rock-salt at the bottom was of very superior quality. At the present time, mining operations are confined to thicknesses of 22 feet in the upper mine and of 22 feet in the lower mine.

The same winding-engine is used for both mines, a larger drum and a longer rope being used for the bottom mine than those used for the upper mine, the difference in the weight of the load being made up by a balance-weight on the rope of the upper mine. Cages are not used in the shafts. There are two guide-ropes, EE, in each shaft, and guides, D, are attached thereto (fig. 5, plate x.). The rock-salt is loaded in the mine into large wooden hoppets, locally called "rock-salt tubs." These hoppets, placed on the frame of a bogie, are not attached to it in any way, and when fully loaded they contain about 1½ tons of rock-salt. They are trucked to the shaft-bottom by the men who load them. The empty tub goes down the shaft and is placed on a bogie waiting to receive it, the three hanging chains,

attached to it, are unhooked and the bogie and the empty tub are pushed away; the bogie and the loaded tub are moved into the place of the empty tub, and the three chains are hooked and the loaded tub hoisted to the surface.

There are two systems of signalling, one being electric and the other by an ordinary signal-line, pulled by hand, which actuates a hammer and gong on the surface. Similar return signals are also employed, the one system of signalling being simply a standby for the other in case of failure.

The dip of the strata necessitates the use of several compressed-air haulage-engines in the mine. Air for driving the haulage-engines, the undercutting machines and the drills, is supplied from an air-compressor, fixed on the surface, capable of dealing with 2,250 cubic feet of free air per minute. The air has a pressure in the mine of about 70 pounds per square inch.

The upper and lower mines are lighted by electricity; Cooper-Hewitt mercury-vapour lamps have been found extremely effective for this purpose; while for general lighting, and in other places for local lighting, tantalum-lamps have now taken the place of ordinary carbon-filament incandescent lamps. No gases of any description are encountered in the rock-salt beds, and natural ventilation is found to be all that is required, assisted by the exhaust-air from the various engines.

The mine is capable of turning out 3,500 tons of rock-salt per week, containing an average of 96·5 per cent. of chloride of sodium. About one half of the present output is consumed at the various works of the United Alkali Company, Limited, at Widnes, St. Helens, Runcorn, Flint, Glasgow, Irvine and Bristol. This portion of the output is ground by specially designed machinery to a fine grain, and it has been the means of ousting higher-priced manufactured salt from the various chemical processes of the United Alkali Company, Limited. This grinding process is peculiar, inasmuch as it mechanically removes the marl-impurities contained in rock-salt, these impurities going from the screens in the shape of tailings. The grinding machinery is capable of reducing 60 tons per hour to the grain of common white salt.

The mine is situated about 1 mile from the estuary of the river Wyre at Fleetwood, and there is a railway of standard gauge to the Company's pier on the river Wyre, where vessels up to

1,500 tons burden can be loaded. A large percentage of the output is shipped direct to the Continent.

In conclusion, the author expresses his thanks to the directors of the United Alkali Company, Limited, for permission to give the information respecting their operations contained in this paper.

Specimens of rock-salt of various qualities and colour, and also of the Keuper marls, overlying the rock-salt, were produced for inspection.

Prof. W. Boyd Dawkins moved that a vote of thanks be tendered to Mr. Thompson for his paper.

Mr. Joseph Dickinson, in seconding the motion, said that Mr. Thompson's paper related to a branch of mining in which he (Mr. Dickinson) had been much interested, having in his time been in every rock-salt mine in England and Ireland. He had been several times in the first shaft sunk at Preesall, and had seen the development as now described. The paper gave the depth of the two workings in the mine, one under the other, and the distance between the supporting pillars, leaving members to infer from the section that a sufficient thickness of rock-salt was left for roof-strength between the pillars. The height of the workings was similar to that of many old mines, but it had been greatly exceeded in recent Irish mines, where the dip was about the same as at Preesall. Under-cutting or holing by machinery had during many years been successfully used in other rock-salt mines. He (Mr. Dickinson) was much impressed with the rapid rate at which the mine had recently been extended, and the increase of brine, by putting water down the bore-holes, from a trickle to a large quantity. The quickened opening was explained by the altered mode of driving out from the shafts, aided by compressed-air drilling-machines. In addition to these modifications, the improved dressing apparatus had been mentioned.

The motion was carried unanimously.

Prof. W. Boyd Dawkins (Manchester) said that he had been very much interested in hearing Mr. Thompson's account of the

occurrence of the red sandstone in the vicinity of the Preesall mine. Large quantities of water were always found in the red sandstone, where there was a fault, as in this case, with the red marl, which was practically impervious, on one side, and the red sandstone on the other. The discovery of rock-salt was extremely interesting to him, because it went to prove the existence of a salt-field under the sea, between the Isle of Man, and Preesall and Barrow in England, and Carrickfergus in Ireland. Some years ago he laid before the members an account of the discovery of rock-salt in Triassic strata in the boring at the Point of Ayr in the Isle of Man, and a thickness of over 70 feet of rock-salt was proved. The brine was now pumped and conveyed in pipes to Ramsey from the Point of Ayr, and the manufacture of salt, on a small scale, had been commenced. The rock-salt round the Irish Sea was of very great geological interest. He could not help thinking that in remote times there was a great salt-basin between the Isle of Man and the Lake country, analogous to the great salt-field of Cheshire.

Mr. John Gerrard (H.M. Inspector of Mines) said that geologically it was extremely interesting to note that at Fleetwood, near Barrow, also in the Isle of Man, and again on the north-eastern coast of Ireland, rock-salt had been proved. At Fleetwood, a bore-hole seeking iron-ore; at Barrow, in the Isle of Man, and at Carrickfergus, the bore-holes were in search of coal. The Preesall mine was probably the most productive salt-mine in this country, and having seen Mr. Thompson's work at the mine he could assure the members that the intelligence which Mr. Thompson had displayed in this paper was fully carried out in the practical work of the mine. He (Mr. Gerrard) had seen in both the upper and lower mines, a band of salt, very crystalline in appearance, several inches thick; the men stated that this guided them in working the salt; and he asked whether this band ran generally throughout the proved mine. He also asked whether it was a fact, where the very pure, very white rock-salt was found, that above or below it, the salt was very impure and mixed with marl. And, lastly, in giving the time occupied in drilling the holes by machine, did the author include the time occupied in fixing and taking down the machine.

Mr. Thompson replied that the seam of crystalline salt was

overlaid by 6 feet of rock-salt and underlaid by 15 feet or 16 feet of good rock-salt. This seam was found in the upper as well as in the lower mine, and indicated the direction of the dip. There was nothing like it found in Cheshire. An analysis of this seam showed that it did not vary from that of the other parts of the mine, except that it was uniformly of good quality and contained no marl, and was softer than the larger bed of rock-salt. It was more like grit, although it was not in any way gritty, and the men called it the "gritty seam."

Mr. JOHN GERRARD asked whether Mr. Thompson had formed any theory as to these guiding crystalline bands and their relation to the seams around them.

Mr. THOMPSON stated that he had not formed any theory as to the relation of the crystalline bands; but they were found in both the upper and the lower mines, and could be relied upon as guides in working the rock-salt.

Mr. JOHN GERRARD said that he had been repeatedly asked by persons interested in brine and salt production why at Fleetwood so large an amount of rock-salt was mined, in addition to the pumping of a large quantity of brine. The mechanical arrangements worked admirably, and the rapid opening-out of the mine, under the conditions obtaining in this case, showed that colliery engineers had something to learn. It was an instance of the advantage of persistent effort in using machinery for opening out mines; and he thought that Mr. Thompson would bear him out in saying that the first machine tried was not altogether a success, as it had to be altered and adapted to the conditions.

Mr. H. STANLEY ATHERTON asked how it had come to pass that these salt-deposits were found so much below the present sea-level. He also asked whether in the working of rock-salt it was easier to cut in one direction than another. In other words, was it similar to working an anthracite-mine, where if the cut was made along the lines of crystallization the work was much easier, and there was an easier line of cleavage and a much better way of cutting.

The PRESIDENT (Mr. Charles Pilkington) directed attention to the supporting shaft-pillars in the Preesall mine, being on a dif-

ferent scale from those deemed necessary in coal-mines. He was astonished at the rapid progress of the tunnelling-machines: 360 feet a week being driven in rock-salt that was harder than coal. He wished that such a speed could be secured in coal-mines: they could not touch 360 feet a week at the mines that he had to do with. He could scarcely believe that rock-salt was harder than coal.

Mr. THOMPSON stated that the tunnelling-machine was worked continuously by three shifts of men, eight hours each. Brine and rock-salt were both worked, because both were required by the United Alkali Company, Limited. Two processes were worked, in one of which salt was required in the shape of brine. The rock-salt was mined mainly to supply the salt required at the works at Widnes and St. Helens, and a considerable quantity was required for export, because rock-salt was admitted at a lower rate of duty than manufactured white salt. Brine was raised from about ten bore-holes, each one being independent of the other, all in the neighbourhood of the Preesall mine. In his experience, a bore-hole became useless, after a certain quantity of salt had been extracted from it. The original level of the sea was not maintained because the land did not retain its level; and there must have been tremendous upheavals at times. Cutting was carried on incessantly, and the cut was made across the face.

Prof. W. BOYD DAWKINS said that salt was merely the result of the evaporation of sea-water. He would expect to find a variation in a thick bed of rock-salt like that at Fleetwood, for the very simple reason that, in various stages of the evaporation of sea-water, different minerals were deposited. It was very largely, therefore, a question of the degree of concentration of the water from which that salt had come. With regard to the present level of the sea, it was quite an accident that rock-salt should be in this relation to it in this place, but in the British Isles nearly all rock-salt was below sea-level. In the vicissitudes of time, after the Triassic rocks had been formed in the sea, they were thrown into a series of folds, and parts of these folds were worn away by denudation; and the salt had been washed out of most of them down to sea-level. Consequently, there was very little rock-salt in Britain above sea-level.

Mr. JOHN RIGBY (Winsford) said that rock-salt was found in Cheshire above sea-level.

Prof. BOYD DAWKINS asked whether it was known that rock-salt occurred above sea-level in any other part of Britain, and remarked that this was an exception to the general rule. There was a large district near Burton, whence the salt had been dissolved out, leaving the broken and disjointed red marls, and in some cases the casts of salt-crystals in the rock, as evidence that it was formerly present.

Mr. DICKINSON said that Mr. Thompson gave the geological view of rock-salt formation, and refrained from expressing his own opinion. Was it not quite possible that the sea obtained its salt from the rock-salt, rather than by the reverse process, namely, that the salt was the result of the evaporation of sea-water?

Mr. THOMPSON thought that it was the accepted theory that the earth was gradually cooling down. If they reversed the process and assumed that the earth was gradually becoming hotter, the water would become steam, and salt would be left. The same rule would apply when the earth was cooling down, and the last occurrence would be that of steam condensing into water.

Prof. BOYD DAWKINS said that the earth was originally in a heated condition, like the sun. As it gradually cooled down, it would arrive at such a stage that chlorine and sodium would combine together in the atmosphere, and a deposit of salt would be formed over the surface; and hydrogen and oxygen combining together, would form water. Thus the sea was salt from the very beginning. The salt-fields of Britain were all derived directly from the evaporation of sea-water.

THE NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD AT THE NORTH STAFFORD HOTEL, STOKE-UPON-TRENT,
APRIL 8TH, 1907.

MR. JOHN NEWTON, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read, confirmed and signed.

The following gentleman, having been previously nominated, was elected:—

ASSOCIATE—
Mr. ALBERT MARSHALL, Florence Colliery, Longton.

DISCUSSION OF MESSRS. W. N. ATKINSON AND A. M. HENSHAW'S PAPER ON "THE COURRIÈRES EXPLOSION."*

Mr. W. G. PEASEGOOD asked what was the cause of the second Joséphine fire, discovered on June 26th, 1906, three months after the explosion.

Mr. A. M. HENSHAW replied that it was believed to have been caused by the explosion, which had been smouldering the whole time, not having been discovered until three months afterwards. The two Joséphine fires were attributed to the flame of the explosion.

Mr. E. B. WAIN asked what were the conditions as to the storage and use of explosives. Were large or only limited quantities taken into the mine?

* *Trans. Inst. M. E.*, 1906, vol. xxxii., pages 439, 340 and 507; and vol. xxxiii., page 124.

Mr. A. M. Henshaw replied that only limited quantities were taken, as they (in England) took them. Explosives were not stored in the mine.

Mr. E. O. Simcock asked what was the amount of explosives in the Lecœuvre heading at the time of the explosion.

Mr. A. M. Henshaw replied that seven cartridges were found intact in the box after the explosion, and he believed that such was the amount given out to the men that morning.

Mr. E. B. Wain asked whether the explosion was sufficiently violent to explode the explosives.

Mr. A. M. Henshaw said that he could not answer the question, but, in many cases, explosives were found intact in different parts of the workings.

Mr. E. B. Wain asked whether average dusty main roads as found in average English collieries were comparable to these roads at the Courrières pits.

Mr. A. M. Henshaw replied that the condition of the main roads of the Courrières pits was very similar to the average main roads of the average English colliery—not more dusty and not less. Of course, the roads were more dusty in some places and less in others, but, generally speaking, they were about on a par with those of an ordinary dry English colliery.

Mr. E. B. Wain asked whether the main roads were packed roads or driven narrow headings.

Mr. A. M. Henshaw replied that the roads were of both classes, but mainly headings. Straight work and longwall was worked; many of the roads were packed roads; but the majority, he supposed, were straight roads driven in the coal.

Mr. Hugh Johnstone (H.M. Inspector of Mines) said that Mr. Henshaw might have been justified in answering Mr. Wain's question, Scotch fashion, by asking another, namely, what did he mean by an average dusty road in an English colliery? He thought that it was practically impossible to fix any standard by which to decide definitely whether a road was dusty or not. The Wingate Grange explosion took place on a main intake road,

with which he was well acquainted, and he had travelled scores of roads in North and South Staffordshire collieries much more dusty than that road in Wingate Grange colliery. It was a road which probably no one present would have considered a dusty one, if they had travelled along it; and yet an explosion originated on it and was propagated along it. With reference to the initiation of an explosion in a mine, where the roads were dusty, and presumably free from fire-damp, he would like to know whether the writers of the paper considered it to be essential that there should be a detonation, as in the Lecœuvre heading; or whether a flame sufficiently large and of sufficiently high temperature would suffice. He thought that it was practically admitted that the imperfect detonation of high explosives in confined places might initiate an explosion in a dry and dusty road. Several cases seemed to establish that clearly; but he was not sure that there were sufficient data available to enable them to determine what size or temperature of flame was necessary to ignite coal-dust without detonation. There was evidence that a sufficiently large flame would ignite coal-dust, but there was almost always a difficulty in proving the entire absence of fire-damp. It was known that a percentage of fire-damp, not sufficient to be capable of detection by ordinary means, could be exploded in a dusty atmosphere; but there was frequently a difficulty in determining after an explosion whether any, or how much, fire-damp might have been present, when the explosion was initiated. To illustrate the facility with which coal-dust might be ignited by a sufficiently large flame, he might refer to an incident which had occurred at a Scotch mine: a tub of dust, filled on one of the main haulage-roads—not on account of suspected danger, but because it was found to be an inconvenience—was sent to bank, and the contents were shot into the fire-hole, to be mixed with the slack for the boiler-fires. The fireman had just cleaned out the fires and the hot clinker lay in front of them. As the dust was shot over, the lighter particles rose in a dense black cloud, and, on their coming into contact with the burning clinker, it was at once ignited, the flame rising 30 feet into the air. There could have been no fire-damp there, and it showed that the dust could be ignited by a sufficiently hot flame. If this was established, it pointed to a serious danger in all dusty mines; because there were several means by which a large flame might be produced. He referred more particularly to the dangers

arising from the use of electricity as a motive power: the cables were usually laid along the intake roads, and no means had been devised of eliminating the danger of a flare-up through a fall of roof rupturing or damaging a cable. He did not know that this had actually occurred, but it was more than possible; and this or any breakdown of the insulation might ignite blowers or local pockets of gas and initiate an explosion. It appeared to him to be worthy of the consideration of mining engineers, because one could easily understand that an explosion of that sort initiated in a dry and dusty main road might sweep the whole pit. The risks were so great that any trouble incurred in eliminating them was repaid. He knew that there were inconveniences from the application of water, but he had an impression that in many cases the difficulties were greatly exaggerated. Of course, a road with a fire-clay floor and deluged with water was liable to heave; but it was not necessary to have a large excess of water percolating through the floor. If water were applied only in sufficient quantity to damp the dust, he questioned whether it would have the effect of making the bad floor that had usually been experienced, simply because an excess of water had been used. That was largely the cause of the heaving of the floor. The authors referred in several places to dust-free spaces; and, accepting the accuracy of their conclusion that these dust-free spaces were a barrier to an explosion, he should like to know whether the authors had formed any opinion as to the length of dust-free space necessary to break or interrupt an explosion. It was mentioned that a distance of 230 feet (70 metres) had been sufficient to stop the explosion, and he should like to know whether there were any other cases showing what length of dust-free space was necessary to prevent the flame from travelling. The authors had also stated that in some of the roads the dust had been shown by analysis not to be highly inflammable. He should like to hear an expression of opinion from the members as to the disadvantage and the danger that might arise from an admittedly non-inflammable dust. Travelling along turnpike roads, they knew the inconvenience of being enveloped in a dust-storm, which rendered respiration practically impossible; but what would be the result of that dust-storm, in the confined space of a mine, lasting for, not a few seconds, but half an hour? There was a possibility that many of the deaths reported as due to asphyxiation had been

really due to suffocation by the action of non-inflammable dust, which had not subsided before life was extinct; and, consequently, the treatment of dusty roads should not be limited to those coated with inflammable dust; but all dusty roads whatsoever should be treated. The writers stated that the three fans were not injured by the explosion, and he should like them to say whether any special precautions were taken in the erection of the fans by placing them some distance from the pit or protecting them with safety valves; or whether their immunity from injury was simply due to the explosion not having reached them. The members were under enormous obligations to Messrs. Atkinson and Henshaw for the trouble that they had taken in communicating this careful study of the explosion and of the lessons to be drawn from observed facts; and the following of their arguments to a logical conclusion might have the effect of minimizing the risk of dust-explosions in that district, and of saving many lives.

Mr. W. G. Cowlishaw said that Mr. A. H. Stokes had enunciated another theory as to the origin of the explosion.*

Mr. William Lockett asked whether the authors were entirely satisfied that fire-damp had nothing to do with the ignition of coal-dust. In his experience, he had known very sudden outbreaks of gas. In 1883, a sudden outburst of gas filled the workings for a distance of 7,200 feet: this occurred at a fault, but fortunately no life was lost, although there might have been, inasmuch as at that particular period the ordinary Davy lamp was in use, and not until afterwards was the Marsaut lamp introduced. In 1886, another outburst of gas took place in a goaf and again filled the workings, and he wondered whether a sudden outburst of gas might not have been concurrent with the firing of this shot. He (Mr. Lockett) suggested that fire-damp might have been liberated by the shot fired in the Lecœuvre heading, or from the fault, crossing the heading parallel to the Lecœuvre heading, or from one of the large faults that crossed the coal-field. It was stated that: "nevertheless fire-damp was not entirely unknown, as it is recorded that, in 1904, a miner was burnt by fire-damp, ignited by a naked light,"† and that the "regulations . of the Pas-de-Calais mines-inspection district require safety-lamps

* *Trans. Inst. M. E.*, 1906, vol. xxxii., page 341.

† *Ibid.*, page 454.

to be used in headings and stone-drifts."* It was rather striking, taking the huge amount of old workings or goaf into consideration, that this stipulation should be in force, and that open lights should be allowed in other parts of the mine, practically in the same ventilating district.

No. 3 pit, a winding, downcast and upcast shaft, divided by wooden partitions, was the ventilation centre of a large district, and situated at distances of 3,800 and 4,200 feet from Nos. 2, and 4 and 11 pits respectively. He (Mr. Lockett) asked whether this single pit was sufficient for the ventilation of the area of workings governed by its position. Further, the use of wooden partitions rendered this pit liable, in case of accident, to become impassable; and, after the explosion, this shaft was completely blocked by débris at a depth of about 500 feet.

Mr. E. B. WAIN thought that North Staffordshire engineers were generally convinced that coal-dust *per se* was an explosive agent, and whatever might have been the primary cause of ignition in this particular case, whether it was a blown-out shot, whether (as had been suggested by Mr. A. H. Stokes) some one had been tampering with explosives and caused a small explosion, or whether (as suggested by Mr. Lockett) there had been a small gas explosion in the Lecœuvre heading, there seemed little doubt that coal-dust propagated the explosion throughout the whole area. The analyses raised the question as to whether certain dusts were incapable of propagating flame. Many years ago, Sir Frederick Abel† obtained explosive results with magnesia-dust in a mixture of $2\frac{3}{4}$ per cent. of fire-damp and air, not inflammable *per se*, and if that inert substance was capable, shale might also be capable of propagating an explosion. This accident had proved very clearly that it was not desirable to couple large groups of workings together in the rough-and-ready way in which they appeared to have been connected at the Courrières collieries, so that an accident in one might affect the whole. Some of them had learnt that lesson already, but he thought it was a lesson that might still be thought over with advantage.

* *Trans. Inst. M. E.*, 1906, vol. xxxii., page 444.

† *Report on the Results of Experiments made with Samples of Dust collected at Seaham Colliery*, by Prof. F. A. Abel, 1881 [C.-2923], page 9; and *Final Report of H.M. Commissioners appointed to inquire into Accidents in Mines*, 1886 [C.-4699], page 155.

Mr. F. H. WYNNE said that there was one point against the theory of the explosion originating at the powder-box. This box was found a long way from the face, a considerable distance outbye from where the mutilated body of the fourth man lay; and it was found practically intact, the cartridges served out in the morning were in it and were not exploded, so that unless there was a second powder-box in the heading, which seemed unlikely, there was not much possibility of the coal-dust having been ignited by that means. This explosion taught the necessity of isolating one district or seam from another by the requisite length either of thoroughly watered roadway or of bricked arch, which, whether white-washed or not, could be kept clean and free from dust with very little difficulty. At Wingate Grange, a workman, firing an explosive, through ignorance apparently, caused a disaster which cost twenty-four lives; and a somewhat similar case occurred recently in North Staffordshire. He thought that it was the duty of every manager to drill into the minds of firemen and shot-firers the dangers of the explosives which they were using, and the necessity of complying absolutely with the conditions laid down in the Home Office Order for the use of explosives in dusty or in any other mines.

Mr. J. GREGORY asked whether the special method of timbering adopted at the Courrières collieries* had prevented or minimized the heavy falls, which as a rule obstructed the work of rescue following upon an explosion. Another question arising out of the discussion was the indefinite information regarding the conditions under which coal-dust was liable to initiate or propagate an explosion. He believed that, even at the present day, there were mining engineers who would not admit the danger of coal-dust in an atmosphere free from gas. They were in a minority; but even amongst those who had accepted the fact and had studied the question there was no certainty as to the relative immunity of coal-dust mixed with metal-dust, as compared with pure coal-dust. It was generally agreed that a length of wet road-

* "Methods of Preventing Falls of Roof adopted at the Courrières Collieries," by Dr. C. Le Neve Foster, *Mines and Quarries: General Report and Statistics for 1899*, page 74, and *Trans. Inst. M. E.*, 1900, vol. xx., page 164; and *Report to His Majesty's Secretary of State for the Home Department on the Methods of Preventing Falls of Roof adopted at the Courrières Collieries*, by Messrs. W. N. Atkinson, C. Le Neve Foster, John Gerrard and Henry Hall, H.M. Inspectors of Mines, 1901.

way, or a length from which the dust had been removed, would isolate an explosion; but, so far as he was aware, there were no data which would enable one to determine with certainty what minimum length would prove effectual. He suggested that experiments ought to be made on a large scale in an experimental gallery. The Government had provided a gallery for the testing of explosives; and, failing any action by the Government on this important question, this work might be undertaken by The Institution of Mining Engineers in order to decide the relative susceptibility of the various classes of dust and the efficiency of the several suggestions for isolation.

Mr. M. Walton Brown wrote that Messrs. H. Le Chatelier, chief inspector of mines; de Morgues, mining engineer at the Blanzy collieries; and Cordier, delegate-miner, appointed to report in the judicial enquiry, had suggested five causes of the explosion:—(1) The fire in the Cécile seam; (2) a shot in the Lecœuvre heading might have ignited a small volume of fire-damp, initiating a general dust-explosion; (3) an ignition of dust: the suggestion of a general explosion of dust, ignited by a shot, made by Messrs. H. Cunynghame and W. N. Atkinson,* had not been accepted; (4) the explosion of a small volume of fire-damp at or near the face, ignited by the flame of an open lamp; and (5) the clandestine and unlawful storage of explosives in an air-pipe in the Lecœuvre heading. The force of the explosion in that heading was most formidable and inexplicable, because the minimum force was most generally found at the seat of an explosion.

The experiments of the committee of The North of England Institute of Mining and Mechanical Engineers had shown conclusively that:—"(1) The high explosives . . . are less liable than blasting-powder to ignite mixtures of air and coal-dust, with or without the presence of fire-damp. These explosives cannot be relied upon as ensuring absolute safety. (2) The experiments have shown that ignitions of mixtures of air and coal-dust, with or without the presence of fire-damp, can be obtained when there is present a much smaller quantity of coal-dust than has been previously supposed to be necessary."† Five ignitions of coal-

* *Report to H.M. Secretary of State for the Home Department on the Disaster which occurred at Courrières Mine, Pas de Calais, France, on March 10th, 1906,* by Messrs. H. Cunynghame and W. N. Atkinson, 1906 [Cd.-3171].

† *Report of the Proceedings of the Flameless Explosives Committee of the North of England Institute of Mining and Mechanical Engineers,* 1896, page 103.

dust in suspension were recorded in their experiments with unstemmed safety explosives (Table I.);* and blasting-powder ignited coal-dust, in suspension and *in situ*, in 28 out of 32 experiments (Tables I, K, L and M).† It was possible, therefore, that an ignition of coal-dust, in the entire absence of fire-damp, resulted from the improper firing of an explosive.

Mr. H. JOHNSTONE said that some years ago the idea was put forth that coal-dust might be removed by a system of aspiration —the vacuum-process of to-day; and when that idea was mooted it was laughed at as impracticable. Anyone conversant with mining knew that the removal of the dust throughout the whole of a mine by such means would be impracticable; but the system might be applied to the removal of dust from short spaces, especially if these spaces were bricked and arched as Mr. Wynne had suggested. Vacuum-cleaners could be introduced at small cost, and power could be easily applied to work them.

Mr. A. M. HENSHAW, in reserving his reply to the discussion, said that he must acknowledge his indebtedness to his assistant, Mr. McGowan, for the admirable plans attached to the paper.

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* *Report of the Proceedings of the Flameless Explosives Committee of the North of England Institute of Mining and Mechanical Engineers*, 1896, pages 96, 118 and 121.

† *Ibid.*, pages 122, 127, 129 and 133.

THE NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE NORTH STAFFORD HOTEL, STOKE-UPON-TRENT, JUNE 3RD, 1907.

MR. J. C. CADMAN, PAST-PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read, confirmed and signed.

The following gentleman, having been previously nominated, was elected:—

MEMBER—

Mr. H. T. PEBWORTH, Asylum Villas, Cheddleton, Leek.

Mr. F. E. BUCKLEY's paper on "Outbursts of Coal and Gas in the Cockshead Seam, Shelton Colliery," was read as follows:—

OUTBURSTS OF COAL AND GAS IN THE COCKSHEAD SEAM, SHELTON COLLIERY.

By F. E. BUCKLEY.

Introduction.—Outbursts of coal and gas had been unheard of in North Staffordshire until the past few years, and it is thought that on account of those which have occurred in the Cockshead seam, worked at the Deep pit at Hanley, might be of interest to the members.

The Cockshead coal-seam lies at a depth of 2,550 feet from the surface, and has an average thickness varying from 7 feet to 7 feet 6 inches. The upper portion, about 3 feet 6 inches thick, is usually of a softer nature than the lower portion. The roof is strong grey metal, with bands of rock, and the floor is a strong dark stone. The general inclination of the seam varies from 14 to 17 degrees, from east to west. There are, in an area within 1,500 feet of the shafts, numerous small faults usually running north-west and south-east, and north-east and south-west.

Each outburst, described in this paper, occurred at a point where a fault intersected the seam; and, in each case, where the coal, at the point of contact with the fault, became light, porous, friable, and dull in appearance, for a width varying from 18 inches to 3 feet.

With the exception of the last occurrence, there had been no indications whatever that an extraordinary quantity of fire-damp was present; but, prior to each outburst, one or two unusually heavy "goths" or "bumps," sometimes accompanied by a peculiar grinding or rending noise, had taken place. Heavy goths were, however, of frequent occurrence in this seam when heading out, and no special importance was attached to the goths preceding these outbursts; especially, as in many cases, it had been thought that the goths did not arise from any severance or movement of the coal, but from the roof.

First Outburst.—The first outburst occurred in a rise heading, A (fig. 1, plate xi.), where a roll had been met with, and the

coal was of the hard, dull character frequently seen in the vicinity of faults. This heading was 12 feet in advance of the line of the top level, which was then within 8 feet of intersecting it.

At 3 p.m., on September 24th, 1903, a collier was engaged in cutting coal on the north side of the heading on the roll, when a terrific goth took place, dislodging a large quantity of coal and releasing a huge volume of gas (figs. 2 and 3, plate xi.). The loader, whose light was extinguished, 15 or 20 feet from the face, saw or felt the rush of coal; he shouted to the collier, and receiving no reply, he fortunately rushed out for assistance. Otherwise, he would undoubtedly have been overcome by the large quantity of fire-damp, which immediately filled the heading, A, and the main level to B (fig. 1, plate xi.).

Officials, on the scene within 5 minutes of the occurrence, could not proceed beyond B, owing to fire-damp being present in great quantity, and steps were taken at once to remove it. Eventually it was cleared to the bottom, C, of the rise heading (fig. 1, plate xi.). Another heavy goth then occurred, and the level was again filled with fire-damp to the point B. The operations were recommenced, and progress was made until the jig-post, *d*, could be seen (figs. 2 and 3, plate xi.). A third heavy goth, discharging more fire-damp, drove the workers back again to the bottom, C, of the heading; but, the goths having ceased, the fire-damp was removed sufficiently, and the body of the collier, *g*, was recovered 4 hours after the outburst. On examination, he was found to have received severe injuries to the face sufficient in themselves to cause death, indicating that he had received the force of the outburst of material immediately in front of him, or that he had been blown either against the roof or the timber. The body was found upon the blown-out material, and there was practically no material lying on the man. The section (fig. 3, plate xi.) shows the position assumed by the blown-out material, *hi*, and the amount of coal, *ef*, thus displaced was approximately 10 tons. This heading was continued about 40 feet in order to prove the fault, but was carried no further (fig. 4, plate xi.).

The detailed plan and sections of the rise heading (figs. 4, 5 and 6, plate xi.), show that the roll was very irregular in its contour, and that there was a considerable difference on the

two sides of the heading. The theory advanced at the time was that a large quantity of fire-damp was contained in a small area or pocket of the dull friable coal, under very great pressure; and that the collier, cutting near one of the ridges of the roll, had so weakened the harder crust surrounding this area that ultimately the pressure overcame the resistance and the occluded gas suddenly burst out.

Second Outburst.—The second outburst occurred in a rise thirling, which was being driven between two levels running to the north. Two men were engaged there, and both of them were killed.

For a distance of 450 feet, the top level had been driven alongside a downthrow fault, which ran irregularly on the rise side of it. This fault caused no trouble, except in the timbering; but, owing to its irregular course, it was touched frequently, without, however, revealing any undue pressure, and at various points it made a quantity of water, which soon dried up.

On one occasion along this length, a collier was cutting the top coal in a kneeling position, when some heavy goths occurred, which he stated "lifted him up off his knees." No special importance was, however, attached to this occurrence, for, as above stated, the seam is subject to goths, which at times are very severe, and frequently release much fire-damp. The coal was very strong, and it was noticeable that the goths did not set free any considerable quantity of fire-damp.

In due course, the rise thirling was commenced; and, as the fault had crossed the top level, it was expected that it would be found in this thirling. On February 12th, 1904, the thirling was driven upward, a distance of 50 feet to D (fig. 1, plate xi.), in hard coal; and was rapidly approaching the fault, when at 7·20 p.m., a tremendous goth took place. In the words of the colliers who were working in the top level, "it sounded as if the whole earth was tearing up." This so alarmed them that they hurried down to the main level; and, hearing nothing from the rise thirling, they managed to reach the bottom of it by crawling below the fire-damp, which, however, increased so rapidly as to cause them to withdraw.

Efforts were at once made to reach the rise thirling, but the fire-damp was present in such great quantity, that it took 2

hours to reach the body of the collier, *o*, who was found lying on his face 25 feet up the thirling (figs. 7 and 8, plate xi.). Artificial respiration was unsuccessful; and, his mouth being full of coal-dust, the medical opinion was that he had been asphyxiated, no other injuries being found.

The body of the loader, *n*, was reached 4 hours after the outburst, his legs having been pinned under some timber and roof, which had fallen or been displaced at the time of the outburst. Although he had received severe injuries, yet medical examination showed that the immediate cause of death was asphyxiation. After clearing the thirling of fire-damp and débris, it was found that coal had been blown out from the point of contact of the seam with the abovementioned downthrow fault. The force of the outburst had blown out six bars, broken the jig-post, *m* (a larch-post, 10 inches in diameter), and caused a heavy fall of roof.

There was every indication that the collier had been cutting the coal, thus weakening the crust of good coal, *gh*, against the fault (which had a thickness of 3 feet of this dull sooty coal, *ik*, lying against it). He had then gone from the face, probably to put a sharp blade on his pick, leaving the loader at the face, when suddenly the outburst took place, and he was overcome by shock and fire-damp before he could get away.

This outburst was so severe, that it affected the level and roads in the vicinity. The roof in the adjacent roads became broken, and a large proportion of the bars in the main level, then 150 feet in advance of the rise thirling, were broken at the moment of the outburst, and the pillar of coal between the two levels was shaken. The force of the outburst was extremely heavy, evidently relieving a considerable area of an abnormal pressure. It was afterwards noted that the coal was even stronger to cut than previously, and that it made practically no gas for some time afterwards. The lower level was subsequently carried through the same fault, but no indication of gas or abnormal pressure was noticed there.

In consequence of the disastrous effects of these two outbursts, and in consequence also of the difficulty of foreseeing them or of preventing their recurrence, it was decided that the only practicable precautionary method was to adopt a system of ad-

vance bore-holes in all level and rise headings. This was hardly expected to prevent such outbursts, but it was hoped that possibly some indications would be given of the near proximity of any enormous pressure, such as had already been encountered. Bore-holes, 2½ inches in diameter, were at once put in as far as possible with a Burnside long-hole boring-machine; the heading was then cut to within 9 feet of the extremity of the bore-hole; and then another hole was bored. In the case of approaching the supposed position of a known fault, or of frequent goths taking place, one and even two flank bore-holes were also bored to test the pressure; and, in a few instances, considerable quantities of gas, as well as water were tapped and relieved. In no case was there any sudden appearance of gas under pressure in the bore-holes; and it is, therefore, by no means certain that any bore-hole has encountered an area of pressure similar to those which produced the fatal accidents just described. Some of the holes were frequently filled with crushed coal as soon as they had been bored; but, beyond this, nothing extraordinary has occurred, although these bore-holes have been continuously maintained in narrow headings.

Third Outburst.—The third outburst occurred at a depth of about 2,800 feet, where two levels were being driven 90 feet apart. It was noted that the coal at the face of the top level was all "on the work": and that, in place of an occasional goth, there occurred a series of goths, following each other at short intervals. The collier was kneeling on the bench of bottom coal cutting the top coal, when a goth much heavier than the rest knocked out a bar; and, immediately afterwards, the full face of top coal, 10 feet wide by 3 feet 6 inches in height, suddenly burst outwards at E (fig. 1, plate xi.), and partly buried the collier. The estimated quantity of coal thus displaced was 2 tons; and, at the same time, the heading was filled with firedamp for a distance of 10 to 15 feet back from the face, although ventilating pipes, 18 inches in diameter, were fixed to within 2 feet of the face.

On removing this débris, it was found that an upthrow fault of about 18 inches, running north-west and south-east had been bared, and that 18 inches of the dull sooty coal had lain against it. The goths had ceased, and the coal on the upper side of the fault was of its usual appearance.

The bearing of this fault was taken, its position in the main level and in the next rise thirling estimated, and this information given to the officials. The colliers were specially warned of its position; and ordered, should anything unusual occur, to withdraw at once, and fetch out the top-level men as soon as possible, as the air-current would pass on to them from the main level.

The rise thirling was commenced in due course, and an extra flank bore-hole was put in to meet the fault. This hole gave off water only; but the centre bore-hole was giving off water and sufficient gas to fire in a safety-lamp at the outer end of the hole. The fireman, on examining this thirling at 7 a.m. on January 24th, 1907, heard peculiar gurgling noises at the face; but this gave rise to no apprehension, as it was considered that it was caused by the water at the extremity of the bore-hole.

At 12·30 p.m. on the same day, he again examined the thirling; the face was then working considerably, the gurgling noise was continuing, and frequent goths were taking place. Within half an hour, a very heavy goth occurred, causing the men to withdraw from the face; and this was followed in a few minutes by the face of coal, F (fig. 1, plate xi.), suddenly bursting away, followed by some roof, adjoining the slip of the fault, which liberated a quantity of water and fire-damp, the latter filling the thirling for the whole of its length of 54 feet down to the landing-plates on the level.

The water washed the displaced coal (54 cubic feet) and dirt (162 cubic feet); and distributed it on the floor of the thirling, and to a depth of 6 inches on the landing-plates at the bottom.

The top-level colliers were fetched out at once, no one being injured and no lights extinguished. In this case also, the goths discontinued immediately after the outburst. The fault was again proved at G (fig. 1, plate xi.) in the main level; but, although centre and flank bore-holes were put in, no extra pressure was encountered, the outburst in the thirling having evidently relieved it over this area.

Conclusions.—From the foregoing descriptions, it will be seen that prior to each of these outbursts an unusual number of goths occurred; and, although the seam is subject to goths in its normal condition, the writer is of opinion that such areas

of great pressure, can, to a limited extent, be located by carefully noting these goths, and serious accidents can be avoided by the use of advance bore-holes and by the withdrawal of men until the disturbances should subside. In the last outburst, there can be little doubt that a fatality would have occurred, unless the bore-holes had been maintained and the experience gained from previous occurrences acted upon.

It is difficult to suggest any reason for the occurrence of these patches or pockets of coal containing fire-damp under such great pressure in the particular locality with which this paper deals. The Cockshead seam has been worked for many years to the south-east and to the north-east, but at shallower depths. At the time of the occurrence of these outbursts, this seam of coal was being opened out at practically the same depth at the adjoining colliery on the north; but, so far as the writer is aware, no similar occurrence had ever been met with either in this or any other seam at neighbouring collieries. It therefore appears that the depth has no bearing upon the occurrences above recorded.

What seems to have some greater bearing upon the question is the fact that the large downthrow north-and-south fault of 300 feet, known as the Far Green fault, splits up into two faults as it passes southwards on the west of the Deep pit. One of these faults, with a downthrow of about 66 feet, maintains the general direction of the main fault; and the other, a downthrow fault of 150 feet, takes a south-easterly direction. The area of strata, contained within the curve formed by the severance of the larger fault from the main fault, is broken up by numerous small dislocations; and it is at these dislocations that the outbursts have occurred. These dislocations are more numerous in the Cockshead seam than in any of the upper seams, and the Cockshead seam is much less disturbed in the north, where the Far Green fault makes one direct step of 300 feet. It may, therefore, be suggested that in the process of faulting, the seam had been subjected to abnormal pressure, and thereby isolated patches of disintegrated coal had been formed, such as have produced these outbursts.

An analysis of the blown-out coal throws no light upon the subject, as it is practically the same as that of the normal seam.

A considerable extent of longwall-face has been opened out to

the north of the site of these occurrences, and there have been no indications of fire-damp under great pressure in this face. It is only fair to say, however, that the face is comparatively free from faults; but, when the longwall method of opening out this seam was decided upon, it was hoped that the larger area of coal exposed at the face would ensure that any accumulation of excessive pressure would relieve itself over a wider area than could be the case when it was approached only by a narrow heading.

The CHAIRMAN (Mr. J. C. Cadman) said that Mr. Buckley had given the members an historic record of some of those occurrences which now more frequently happened in deep mining, and the information would be valuable to those engaged in that class of work in this or in any other district. This new feature of danger would have to be carefully met, as pointed out in Mr. Buckley's paper.

Mr. W. N. ATKINSON (H.M. Inspector of Mines) wrote that he had investigated the accidents caused by the outbursts of 1903 and 1904;* and it seemed probable that a fatal accident was averted by the precautions taken in the case of the fourth outburst. It appeared difficult to understand the relationship between the goths and the outbursts. Were the goths caused by pockets of disintegrated coal saturated with gas at high pressure? Or were the goths only the means of breaking down the strong coal surrounding such pockets, so as to liberate the disintegrated coal and gas? Although bore-holes were not a certain means of indicating where outbursts would take place, nor of relieving the pressure so as to prevent them, they were advisable where it was thought that outbursts might occur; and the greater the diameter of the holes, the more useful they were likely to be. Alertness to observe and to be warned by indications similar to those noticed in connection with previous outbursts was of the greatest importance.

Mr. J. T. STOBBS said that Mr. Buckley had brought before the members a large number of facts, which, together with the

* *Reports of H.M. Inspector of Mines for the Stafford District for the Year 1903*, by Mr. W. N. Atkinson, 1904, page 24; and *Reports of H.M. Inspector of Mines for the Stafford District for the Year 1904*, by Mr. W. N. Atkinson, 1905 [Cd. 2506—VIII.], page 21.

samples of coal from the various outbursts, were of special interest; but those from the second and third outbursts were very striking samples. He had not had an opportunity of seeing this outburst-coal previously, but he noticed that the pieces were all very finely coated on a few of the sides with chocolate-brown coal-dust, that was to say, coal-dust of the very finest powder. As they looked at coal, it was ordinarily black; but, the finer it was ground, the browner it appeared, and this coating of the finest brown powder suggested that there had been considerable grinding action preceding the actual outburst of the coal. He thought that the outbursts were not due to gas-pressure, because the bore-holes that had been put in would tap the gas, if it existed under such very great pressure, and would prevent the outburst. The intimate connection between the outbursts and the faulted areas, and especially the rolls in the floor, seemed to point to regional disturbances that might have occurred some time previously—it might be years and years before—or might have been induced by the actual workings approaching that area. What was the nature of the floor of the heading, in which the outburst of September, 1903, occurred? Was it broken up or was it in its normal stratified state? Any puckering would indicate that the influence of the fault had extended into the strata. The fact that "the pillar of coal between the two levels was shaken"* pointed to regional disturbances of the measures. The members wanted more facts, placed side by side with one another, so that they could form a working hypothesis of the cause of these singular occurrences; and when they had obtained a scientific explanation of the facts, steps might be taken to guard against the risk and danger attending these outbursts.

Mr. William Lockett said that he had been working the Cockshead seam at an adjoining colliery by the pillar-and-stall and a semi-longwall system for a number of years; and, although coal-outbursts were new to him, outbursts of gas were not. In February, 1883, on approaching a large fault, there was a tremendous outburst of gas, filling the whole of the workings, which extended roughly about 7,000 feet; and, fortunately for themselves and everyone concerned, no further disaster arose. This outburst occurred in the Cockshead seam, at a depth of

* *Trans. Inst. M. E.*, 1907, vol. xxxiii., page 316.

about 800 feet. Another outburst took place in the roof of the Cockshead seam, at a depth of about 900 feet. In this case, the gas was accompanied by a considerable amount of water, which continued to run long after the gas had spent itself. Whilst examining the place, he observed a man, carrying a Davy safety-lamp, running towards him and passing through the explosive mixture; and his feelings on that occasion would be better understood than described. The Marsaut lamp was then introduced, and minimized the danger that existed when Davy safety-lamps were used in the Cockshead seam. He thought that Mr. Buckley had introduced a very wise precaution in approaching these dangerous areas by means of bore-holes.

Mr. A. M. Henshaw said that the members could not ignore the facts that had been put before them by Mr. Buckley with regard to the occurrence of these outbursts: (1) At a great depth; (2) where the seam was faulted; (3) accompanied by outbursts of gas; and (4) where soft, locally called "mushy," coal, was found in the neighbourhood of a fault. It seemed to him that all these conditions had important bearings on the occurrence of these outbursts, and he disagreed with Mr. Buckley that the depth of the workings should not be taken into consideration, and with Mr. Stobbs that gas-pressure had nothing to do with these outbursts. He had tried to picture in his mind the condition of things, and what brought them about; he understood that the great fault divided into two, and that it was in the fork of these smaller faults that the outbursts had taken place; and it seemed to him likely that the long-imprisoned gas, under great pressure, was chiefly responsible. It was on record that bore-holes had been put into seams, properly stopped, and gauges had recorded a pressure of 461 pounds to the square inch.* The conditions here gave them considerable pressure and the gas, under pressure, was locked up in a small pocket of friable coal, which had been disintegrated by fault-action and was not cohesive; and, if a pocket of coal, containing gas at a high pressure, was approached by a heading or a bore-hole which perforated the jacket of that pocket, then it did not seem to him surprising that these outbursts should occur. The depth, the faulting, the soft coal, and the occurrence of gas all had considerable bearing

* "Experiments showing the Pressure of Gas in the Solid Coal," by Sir Lindsay Wood, Bart., *Trans. N. E. Inst.*, 1880, vol. xxx., page 204.

on the question, especially as they were always accompanied by goths, which showed that considerable subsidence-pressure was brought to bear on a local area, and that the pressure, brought about by the driving of the roads, caused the roof-pressure. All the conditions helped to disturb the mass of soft coal containing the gas, and to increase the tension of the surrounding strata, until the moment when the jacket of the pocket was perforated. Then the outburst came, and the gas and the soft coal were discharged at the point of least resistance.

Mr. William Lockett asked whether the Cockshead seam contained 3 or 4 inches of cannel coal, containing a larger proportion of gas than the remainder of the seam.

Mr. A. M. Henshaw said that at a fault, and particularly at a large fault, there was generally a "leader" or "clod," that was, a mixture of all the disintegrated material alongside and between the walls of the fault-faces, produced by the sliding action of the two sides of the fault. Where the fault crossed the coal-seam, the coal was similarly and often extensively disintegrated, the bedding had been destroyed, and the coal could be ground into dust, in their hands. The crushed coal would contain gas, like the coal-seam; but the seam, in its natural condition, would not release its gas so freely as would the mass of soft coal contained in the pocket. When the crust or jacket of the pocket was perforated, the soft coal was not sufficiently cohesive to retain gas, under pressure, and it would relieve and empty itself of the coal and the gas suddenly.

Mr. E. O. Simcock asked how the safety-lamps behaved at the time of the outbursts and the general condition of the lamps when recovered. He had found pockets of gas, not pockets of coal, in the thick coal-seam of Upper Assam, at a depth from the surface of about 120 feet. There was absolutely nothing in them but gas at a high pressure, that was to say, they were quite empty, after the gas came out, except for the atmospheric air. Some extended for a length of 20 feet, and as much as 10 loads of stuff had been filled into them, after the gas had escaped.

Mr. A. Hassam said that he was not in agreement with Mr. Stobbs, when he stated that the outbursts were not due to gas under pressure. Could Mr. Stobbs define what he implied by

a "regional disturbance"? They were very much indebted to Mr. Buckley for bringing this matter forward, and he had much pleasure in moving a vote of thanks to him for his interesting paper.

Mr. F. H. WYNNE said that a similar occurrence took place in 1904, at Sneyd colliery, also in the Cockshead seam. The face was burst off, but there was no fault and no soft coal. It had been described as follows:—

> On August 23rd, at 7.30 p.m.; barometer 29·76 inches, steady. Three fatally injured. This explosion occurred in the Cockshead seam, in a heading being driven to split a pillar of coal, preliminary to its removal. The seam lies at a depth of 875 yards, and is 7 feet 6 inches thick, of clean coal. The pillar of coal which was being split was about 40 yards long by 25 yards wide, and the heading was driven 20 yards in the direction of the length of the pillar, so that the face of the heading was about the centre of the pillar. The heading was about 7 feet 6 inches high by 10 feet wide, and was ventilated by a range of 18 inches air-pipes, led from a brattice-sheet, the end of the pipes being within a few feet of the face of the heading. The place was examined by a fireman at 5.30 p.m., who found it safe and free from gas; and two colliers and a loader went into work at 7 p.m. About half an hour afterwards, a brattice-man, who was working on the road about 100 yards from the face of the heading, heard a very loud goth or concussion of the strata. He went towards the place and heard shouts, and found the three men running out of the heading, the clothing of two of them being on fire. . . . Two of the safety-lamps (extinguished) were found hanging on posts near the face, and the third lamp was found impaled on the brake-handle of the jig-wheel, with the glass broken, the brake-handle having passed right through the glass. The lamp was in such a position as it might be if it had been hanging on the lid over the jig post and had fallen therefrom. It was fitted with a hook for hanging up, and the lid of the jig-post would be a convenient place to hang it for lighting the loader. Before the explosion it had probably been hanging on the lid, and had been shaken off by the goth.*

Mr. A. HASSAM said that the occurrence at Sneyd colliery would be at the nearest point, in the adjoining colliery, to where these outbursts took place in the Cockshead seam, and at or about the same level. Similar occurrences had been described by Mr. Meachem,† and several interesting papers described outbursts of gas in South Yorkshire.

Mr. J. T. STOBBS said that by the term "regional disturbances," he meant strata in bulk undergoing movement, especially intense at local centres, due either to cosmic movements or

* *Reports of H.M. Inspector of Mines for the Stafford District for the Year 1904*, by Mr. W. N. Atkinson, 1905 [Cd. 2506 –VIII.], page 13.

† "Notes on an Earth Explosion or 'Bump' at Hamstead Colliery," by Mr. F. G. Meachem, *Trans. Inst. M. E.*, 1893, vol. v., page 381.

to the draw of the working-faces or goaf. Cosmic movements of the earth's crust gave rise to earthquakes and faults, and were most marked along belts of special weakness, such as fault-lines. There was no doubt that movements of this kind would produce in some places pockets of soft coal, and it was exceedingly probable that in the deeper coal-seams there might be an intimate connection between these outbursts and earthshakes.

The CHAIRMAN (Mr. J. C. Cadman) said that he remembered a very serious outburst of gas, which occurred whilst cutting through a downthrow fault of 300 feet to open out an area of coal that lay surrounded by faults. When the crut was approaching the coal-seam, a small fault of 30 feet was found, running parallel to the main fault, and about 10 to 12 feet distant from it. The strata, between these faults, during the week-end were thrust or forced out, and filled the crut for 20 or 30 feet; and although the inlet and outlet cruts were then about 300 feet long, both were filled with gas on the inbye-side. At the expiration of eight or ten weeks, when the gas was drained off sufficiently so as to allow the men to reach the face, it was found that the strata at the far end of the crut had been forced out from the main fault and doubled over like the leaves of a book. The gas was evidently under great pressure *in situ*, no pockets were perceived, and although no coal was thrown out, he considered that the pressure of gas could have lifted the strata. He had pleasure in seconding the vote of thanks.

The vote of thanks was cordially approved.

Mr. F. E. BUCKLEY, in replying to the discussion, said that arguments could be used in favour of several theories, but at Shelton colliery they were of opinion that the outbursts were caused by pockets of gas under pressure; and, of course, until something different was proved, that argument held good. The samples of coal differed, because the first outburst was entirely different from the other two, in which the burstings were from the side of a fault. The first samples were from the face of a heading and from the side of the heading, on the top of a roll, and there was no dislocation of the roof (fig. 3, plate xi.). If this occurrence was not produced by a pocket of gas under pressure, why was coal burst from the face and from the side of the heading?

This was one of the arguments in favour of the theory of a pocket of gas. Mr. Lockett's experiences at an adjoining colliery were confined to outbursts of gas, followed by a little top coal, and not of coal blown out immediately in advance. The floor at the roll was of the usual nature: it was not broken in any way, but simply altered in its contour, and the stratification followed along the same lines. Each safety-lamp was intact, when found; and it was supposed that each one was extinguished by gas or by concussion, either one or both. The safety-lamps would be hung up, and the goth might cause them to drop to the floor, so extinguishing them, without damage.

The further discussion was then adjourned.

DISCUSSION OF MESSRS. W. N. ATKINSON AND A. M. HENSHAW'S PAPER ON "THE COURRIÈRES EXPLOSION."*

Mr. F. H. Wynne asked whether the authors, in the course of their explorations, had found any dust-free spaces or dust-safe spaces, over which the explosion had passed; and if so, what was the length of these spaces?

Mr. Edw. B. Wain wrote that as the question of the probability of non-inflammable dust limiting a coal-dust explosion had been raised, the following notes from a report by Prof. F. A. Abel† were of interest.

> The results obtained with this particular dust led me to try whether the ignition by a lamp-flame of a mixture of fire-damp and air, not inflammable *per se*, would be brought about by suspending in it a fine readily-floating dust which was quite non-combustible, and not susceptible of any chemical change by exposure to a high temperature. The powder answering to these conditions which was most readily procurable when this experiment suggested itself, was calcined magnesia. A gas-mixture having 3 per cent. of fire-damp was allowed to pass a lamp-flame at a velocity of 600 feet per minute for some time; no result was produced, but on causing it to convey calcined magnesia in suspension long flares of flame were produced within a few seconds of the mixture first passing the lamp, and the inflammation speedily spread throughout the gallery with feeble explosive effect.

* *Trans. Inst. M. E.*, 1906, vol. xxxii., pages 439, 340 and 507; and vol. xxxiii., pages 124 and 303.

† *Report on the Results of Experiments made with Samples of Dust collected at Seaham Colliery*, by Prof. F. A. Abel, 1881 [C.–2923], page 9; and *Final Report of H.M. Commissioners appointed to inquire into Accidents in Mines*, 1886 [C.–4699], page 155.

With only 2·75 per cent. of gas, results quite similar were produced, the general ignition following, however, less rapidly after the first production of the flares in front of the lamp-flame. With another sample of calcined magnesia, which was not quite so light as the first one, a corresponding result was obtained with a mixture containing 3 per cent. of fire-damp.

In a still atmosphere, containing 2·5 per cent. of coal gas, one of the most sensitive of the Seaham dusts (K), when suspended in it, produced ignition of the mixture, with no explosive effect. A corresponding result was produced by suspending calcined magnesia in a still atmosphere containing 3 per cent. of gas.

It will be seen from these results that the perfectly non-combustible powder, magnesia, is, in its power to bring about the ignition of an otherwise uninflammable mixture of fire-damp or coal gas and air, little inferior to the most inflammable and sensitive of the Seaham dust-samples.

These remarkable results led to the trial of a number of other non-combustible powders or dusts, which are not chemically affected by such heat as they would be exposed to in the flame of a lamp (such as kaolin, powdered flint and other forms of silica, pumice, slate dust, etc.) with results similar to those furnished by the magnesia-dust, but more or less affected by variations in the density and other physical properties of the dusts. In experiments with currents of 1,000 feet velocity, the effect of any one of the powders being deposited on the bottom and sides of the gallery, was to cause the instantaneous ignition of a 3·5 per cent. gas-mixture on its reaching the lamp-flame, through the influence of dust-particles carried along by the current, and in some instances a like result was obtained with 3·25 and 3 per cent. gas-mixtures.

Mr. J. T. Stobbs directed special attention to the point raised in the paper that some dusts were apparently harmless, when containing over 60 per cent. of non-combustible material, such as shale or stone-dust. That statement was in direct conflict with Sir Frederick Abel's work and the quotation, supplied by Mr. Wain, proved that statement. Consequently, Mr. Wynne's "dust-safe spaces" was a contradiction in terms, that was to say, if any dust was dangerous.

Mr. F. H. Wynne replied that, if all dust was dangerous, it was a contradiction in terms, but they had evidence in the paper of dusty spaces over which the explosion had not continued.

THE NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

EXCURSION MEETING,

HELD AT TUTBURY, JUNE 24TH, 1907.

The members visited Messrs. J. C. Staton & Company's gypsum-mines at Fauld and plaster-mills at Tutbury, where they were met by Mr. T. Trafford Wynne and shown over the works. Luncheon was kindly provided at Tutbury.

A hearty vote of thanks was accorded to Messrs. J. C. Staton & Company and to Mr. T. Trafford Wynne, for their kindness in allowing the members to inspect the mines and works.

TUTBURY GYPSUM-MINES AND PLASTER-MILLS.

The gypsum-mines of the Dove valley* have been described in the *Transactions*.

The plaster-mills at Tutbury were originally the corn-mill for Tutbury Castle. The whole of the power required on these extensive premises is obtained from turbines, the motive power being furnished by the waters of the river Dove, conveyed in a flume cut in the reign of Henry VII.

The various grades of plaster are chiefly accounted for by the different qualities of gypsum, but various processes are adopted in the manufacture. The finest plaster used for artistic purposes and various other plasters are made by calcining the gypsum in kilns, cleaning it with brushes, and grinding it in mills. Ordinary plasters used for mould-making and for builders' purposes are made by breaking the gypsum, grinding it, and treating it by the process known as "boiling." This consists in placing it on circular hearths, heated from below, and on these the plaster is continually stirred by mechanical means. Keens, Parian and other cements are also manufactured, the processes being more or less secret. It may, however, be said generally that the gypsum is calcined in kilns, treated with chemicals, baked and finally ground.

* "Gypsum, and its Occurrence in the Dove Valley," by Mr. T. Trafford Wynne, *Trans. Inst. M. E.*, 1906, vol. xxxii., page 171.

THE INSTITUTION OF MINING ENGINEERS.

GENERAL MEETING,
HELD IN THE ROOMS OF THE GEOLOGICAL SOCIETY, BURLINGTON HOUSE, LONDON,
JUNE 13TH, 1907.

MR. MAURICE DEACON, PRESIDENT, IN THE CHAIR.

PRIZES.

The SECRETARY reported that the Council had awarded prizes of books to the writers of the following papers, which had been printed in volumes xxx. and xxxi. of the *Transactions*:—

"Mining Fields of Southern Rhodesia in 1905." By Prof. J. W. Gregory.
"Practical Problems of Machine-mining." By Mr. Sam Mavor.
"Rescue-apparatus and the Experiences gained therewith at the Courrières Collieries by the German Rescue-party." By Mr. G. A. Meyer.
"Description of the Sinking of Shafts through Sand at Ardeer, Ayrshire, by the Pneumatic Process, with Notes on the Subject of Caisson-ventilation and Sickness." By Mr. T. H. Mottram.
"Commercial Possibilities of Electric Winding for Main Shafts and Auxiliary Work." By Mr. W. C. Mountain.
"The Value of Fossil Mollusca in Coal-measure Stratigraphy." By Mr. John T. Stobbs.

Mr. MAURICE DEACON read the following "Presidential Address":—

PRESIDENTIAL ADDRESS.

By M. DEACON.

Before entering upon the subject of my address, I desire to thank you for conferring upon me the honour of the Presidency of this Institution for the current year, and in doing so I make no apologies for any lack of ability to fulfil the office to your satisfaction; I can only assure you of the great interest that I take in the Institution, and of my desire to assist in widening its influence for the benefit of the profession and of the public at large.

In endeavouring to review the progress which this Institution and the profession of mining engineering have made during the past few years, I have fully in mind the difficulty of adding to the knowledge of the members in any important degree or of making any statement of a startling or novel character. I therefore propose to cast a retrospective glance at the history of this Institution and of mining engineering during the past quarter of a century, coupled with a few suggestions as to the possibilities of future years.

This Institution was formed in the year 1889, with the object of broadening the sources of information upon matters affecting the profession of mining engineering, by amalgamating the various mining institutions of the Kingdom into one consolidated body; and, with the sole exception of the South Wales Institute of Engineers, I believe that this object has been attained.

In the year 1891-1892, there were 1,401 federated members and 19 non-federated members, contributing subscriptions amounting to £1,060, whilst the working expenses amounted to £1,471. In the year 1905-1906, the federated and non-federated members respectively were 2,972 and 73, whilst the subscriptions amounted to £2,859 and the working expenses to £3,170. This great increase of membership, representing over 100 per cent. in

15 years, can only be regarded as satisfactory, whilst the financial results are also satisfactory, representing as they do an increase in the subscriptions of nearly 170 per cent. and in the working expenses of only 115 per cent., whilst the income from all sources of the year 1906 exceeded the working expenses by £368 and a cash-balance of £1,907 remained, the highest amount since the establishment of the Institution.

In the year 1905-1906, 64 papers were received by the Institution, including 42 from the Federated Institutes. Many of these papers contained valuable information, which was materially increased by the discussions upon them.

The previous decision of the South Wales Institute of Engineers not to amalgamate with this Institution is regrettable, from the fact that the profession at large suffers from the absence of that free interchange of experience and opinion which is necessary for its fullest advancement, and which alone can be attained by the association of all the mining institutions in the United Kingdom. The other allied professions have, I believe, all recognized the benefit of the consolidation of their interests, with the result that civil engineers, mechanical engineers, and electrical engineers, architects, and geologists, have each but one Institute, and there is but one Iron and Steel Institute. With such an example from the allied professions, it would appear that little risk would be incurred in mining engineers adopting a similar course, and it is to be hoped that the South Wales Institute of Engineers will shortly recognize the advantage to themselves and to this Institution, of consolidating into one powerful body the two Institutions, in order that the fullest advantage from the combined deliberations of mining engineers throughout the Kingdom may accrue to the nation.

Perhaps the most striking advancement during recent years is the progress of scientific education. Twenty-five or thirty years ago, the facilities for the scientific training of the younger members of the profession were extremely meagre, and, in fact, it was rarely possible for any person occupying a salaried position at a colliery to acquire scientific knowledge except by the reading of books. It is true that the Universities of Oxford, Cambridge and London existed, and that some of the large centres of industry had their scientific or technical schools; but

these were few and far between, and beyond the reach of the majority of young men employed at mines, excepting those who could afford to spend two or three years in scientific training before commencing practical work. The opportunities for combining scientific with practical instruction were available in very few instances.

At the present time, the existence of technical schools in the heart of every industrial centre brings within the reach of every person desiring to acquire scientific knowledge the opportunity of doing so, without materially interfering with his daily work. The facilities offered to mining students by some of the provincial universities of combining scientific education with practical mining work has, in my opinion, established the best means of training the mining engineers of the future, for the reason that the practical work assists the student in the readier comprehension of the scientific teaching, and that the scientific teaching assists him to comprehend many of the practical problems confronting him in his daily work, from a scientific standpoint.

It is natural that professors should prefer the student to devote the whole of his time to scientific work for a given period, but it is not within the financial reach of many students to do so. Personally, however, I am strongly of the opinion that the sacrifice of two or three years in the initiation of the student into practical work is not calculated to produce the best type of mining engineer, to whom the nation must look for the economical production of its coal and other minerals in the future.

In briefly referring to the safe working of our mines, it is a source of satisfaction to note the improvement which has taken place in the diminution of fatal accidents in relation to output and to the persons employed.

In the year 1882, the output of coal in the United Kingdom was 156,499,977 tons, whilst in 1906 it amounted to no less than 251,067,628 tons, which is equivalent to an increase of 61 per cent. In the same years, the persons employed in and about the coal-mines in the United Kingdom were 503,987 and 882,345 respectively, representing an increase of 75 per cent., whilst the loss of life was 1,126 and 1,142 respectively, an increase of only 1½ per cent. The average loss of life for the 10 years ending December 31st, 1882, was 1,129, and the death-rate per 1,000

persons employed was 2·24, and 7·42 per million tons of coal raised; whilst in 1906 the parallel figures were 1·29 and 4·31 respectively. Such figures as the foregoing can only be regarded as highly satisfactory, and as the result of the more careful management of our mines. Nevertheless, every colliery manager and mining engineer will continue to direct his best efforts to the still greater reduction of accidents. To what further extent the death-rate may be reduced probably depends more upon the carefulness of the men themselves than upon colliery managers, since the principal sources of accident are such as are mainly under their control. The deaths from falls of roof and sides in 1906 were no less than 551, or nearly 50 per cent. of the total loss of life from all causes; whilst 214 were due to haulage accidents, the greater part of which might probably have been avoided by the exercise of reasonable care on the part of the victims. It is a matter for congratulation to every person connected with mining and to the public at large, that the loss of life from explosions of fire-damp was reduced to the low figure of 55 in 1906, or under 5 per cent. of the deaths from all causes, as compared with an average of 263 deaths for the ten years ended December 31st, 1882, which was equivalent to 23 per cent. of the average total deaths over that period.

Many and various suggestions have been made by mining engineers, giving evidence before the Royal Commission on Mines, with regard to the safer working of our mines, the most prominent relating to methods of attempting to arrest the extension of explosions by the aid of coal-dust. Without attempting to criticize the evidence which has been given, it may be stated that the watering of the roadways in and around the points where shots are to be fired must be recognized by all as necessary in dusty mines. Whether the watering of the whole of the main roads can be economically carried out, having regard to the effect of water upon certain floors, roofs and sides, is very doubtful, and it may be safely stated, in view of the varying conditions of mines, that no general rule applicable to all mines in the Kingdom can be wisely made.

Whilst dealing with the death-rate from accidents in mines, it may be interesting to refer to the comparative mortality in other occupations, both from accidents and from all causes. The latest published returns of the Registrar-general are for the

years 1890 and 1892, and for this purpose it will be sufficient to give a very short abstract of the mortality in a few of the principal occupations during those years (Table I.). It is clear that the

TABLE I.—MEAN ANNUAL DEATH-RATE PER 1,000 LIVING ENGAGED IN VARIOUS OCCUPATIONS.

Occupations.	Aged 25 to 45 Years. Per cent.	Aged 45 to 65 Years. Per cent.	Occupations.	Aged 25 to 45 Years. Per cent.	Aged 45 to 65 Years. Per cent.
Sawyers	7·04	23·91	General labourers, London	14·76	38·14
Carriage-makers	8·86	30·74	Ironstone-miners	7·00	22·02
Wheel-wrights	6·55	24·48	Tin-miners	10·41	46·59
Ship-wrights	7·11	20·01	Stone and slate quarries ..	10·75	34·62
Wool and worsted manufacture	9·08	29·37	Coal-miners :—		
Cotton, flax and linen manufacture	9·39	34·11	Durham and Northumberland	6·60	23·07
Lace-manufacture ...	6·53	21·18	Lancashire	8·63	31·55
Hosiery-manufacture ..	7·23	20·89	West Riding of Yorkshire	7·20	26·46
Paper-manufacture ...	7·18	27·75	Derbyshire and Nottinghamshire	5·98	21·41
Potters, etc.	12·98	52·78	Staffordshire	7·19	30·28
Glass-manufacture ...	14·11	40·83	Monmouthshire and South Wales... ...	9·90	33·27
Railway platelayers and railway labourers ...	10·52	30·41	All males	9·99	28·30
Costermongers, hawkers	19·65	42·10			

NOTE.—The Report of the Eight Hours' Day Departmental Committee stated that in the 10 years from 1890 to 1892 and 1900 to 1902 the mortality of all coal-miners had decreased 20·8 per cent., and all other "occupied males" 16·1 per cent.*

occupation of the miner is not of an unhealthy character, and that it compares favourably with most other occupations (having regard to the fact that the death-rate from accidents exceeds that of many of the other occupations) and with the average of "all males." Any opinions which may have been formed by those unacquainted with the working conditions of the British coal-miner's life, to the effect that the occupation is unhealthy as compared with other occupations, may therefore be banished from their minds.

During the year 1906, three important Acts of Parliament affecting the mining industry were passed, namely, the Workmen's Compensation Act, the Trade Disputes Act and the Census of Production Act. By the first-named Act a further burden will be placed upon colliery owners and the public from July 1st next. The extent to which this Act will affect the cost of production remains to be seen, but that it will be greatly increased is indisputable, and this is evidenced by the largely increased premiums that insurance companies are demanding upon their present scales.

Among other items of legislation in regard to the working of

* *Final Report of the Departmental Committee appointed to inquire into the Probable Economic Effect of a Limit of Eight Hours to the Working Day of Coal-miners*, 1907 [Cd. 3505], part i., page 48.

mines, the following bills have been promoted in Parliament, namely, the Coal-mines Regulation Bill, Engines and Boilers (Persons in Charge) Bill, and two Bills for limiting the period of working underground. The proposal to disturb again the Coal-mines Regulation Act (which has had but a short period of existence, and during which a marked improvement in the death-rate from accidents has occurred) appears to be unnecessary and undesirable, and likely to introduce fresh difficulties in the management of our mines, coupled with an increased cost of production. The proposals of the Coal-mines (Eight Hours) Bill is fraught with serious danger, not only to the industries of the country and to the public at large, but to the very men in whose supposed interests the promoters introduced their Bills. At the present time, few miners work over 8 hours in one day, and this cannot be regarded as excessive, in view of the fact that the average number of days worked per week over the whole country is less than five. By the passage of such an Act, the time available for coal-working would in many cases not exceed 6 hours per day, and in those mines where the working-face is situated a very long way from the pit-bottom, probably not more than 5½ hours. The effect of such a serious limitation, apart from the injustice to the industrious workman anxious to make provision for the future comfort of himself and his family, would be to increase the cost of production so seriously that those industries which are of necessity large consumers of coal, especially the iron and steel trades, would be seriously prejudiced in competition with foreign countries, to the grave detriment of the trade of the country generally; whilst the household consumer, and especially the poorer class, would suffer great hardship by the increased cost of fuel for house-consumption. To what extent the price would rise, it is, of course, impossible to suggest, but that a reduction of 20 to 25 per cent. in the output, which would probably accrue, would result in a great scarcity of coal, and that such a scarcity would result in a great rise in the price, cannot be questioned. In an experiment made some years ago to test the practical result of such a limitation of hours of working, I found that the output of a certain colliery was reduced by 27 per cent. below the output obtained on a normal day of 9 hours' winding. It is, therefore, to be hoped that the Legislature will refrain from entering upon a step pregnant with such serious results to all sections of the community.

With regard to future legislation, it appears desirable in the interests of lessees and of the country at large that the power of a mineral-owner to decline to lease or sell his coal, in the case of small areas, upon reasonable terms, where such refusal would result in the coal remaining unworked, and the withholding of wayleave-rights or the imposition of unreasonable terms for such rights, should be dealt with by Parliament.

Whilst on the subject of legislation, it may be interesting to allude to the important question of the right of a surface-owner to support of the surface. It is now well known to every mining engineer that, where the ownership of the surface is separated from the ownership of the minerals, the minerals may not be worked so as to let down the surface except by consent of the surface-owner. It is not, however, generally known that an action is pending in the courts in which the right of the lessee to let down the surface, where both the surface and the minerals belong to the same lessor, is being challenged, notwithstanding the fact that by a provision in the lease it is set out that the coal shall be worked by the longwall method. If this claim be upheld by the courts, it may be stated without contradiction that the majority of the leases now existent will be of value to the lessees only by the goodwill of the lessors. Many old leases contain no specific power to let down the surface, but in view of recent and possible future judgments, no new leases should be made without such a provision..

The improvement in the working of collieries during the past twenty-five or thirty years has not been confined to the great and satisfactory diminution in the number of accidents in relation to the output of coal. Considerable progress has been made in the economical working of coal by the adoption of the longwall system in those districts where the pillar-and-stall method was to a large extent in operation, whereby economies in working, improved ventilation, and the more complete extraction of the coal have taken place, whilst the proportion of small coal to large has been considerably reduced.

Great progress has been made in the mechanical engineering of collieries, the development of perhaps the most striking prominence being, the use of electric power. Twenty years ago it was considered by mining engineers and colliery managers a

dangerous expedient to use electric current in the underground workings of fiery mines, and even within the past 10 years it has been so regarded in South Wales. The adoption of the alternating current, the use of enclosed motors, oil-immersed switches and fuses, and the encasing of cables or burying them in the floor, have, however, gone far to remove the fears which then existed, with the result that it is now generally admitted that this useful method of transmission of power for hauling and pumping may be adopted with safety in most mines. Its application for haulage purposes, not merely on the main roads, which in itself is frequently a matter of economy and convenience in the case of deep shafts, but particularly to auxiliary ropes employed for the purpose of feeding the main ropes, has done much to reduce the cost and increase the efficiency of the conveyance of coal from the working-face to the pit-bottom.

In seams which are worked to the dip, it is now a common practice to employ mechanical haulage to the entire exclusion of horses; and, in Warwickshire, where several seams are worked in conjunction with one another and brought to one main gateroad, it is the custom to employ a small haulage-set on every gateroad, as well as on the subsidiary levels or cross-gates.

In underground pumping, where small volumes of water require to be pumped at various points in the workings, great economy has been effected, as well as in the case of small shaft-pumps of the three-throw, high-speed, or centrifugal types.

By the use of steel props and girders, economies have been effected in some mines of fully 1d. per ton upon the coal raised, and there is little doubt that their use might be adopted and extended in many mines with successful results. Making allowances for breakages and losses in an average mine, the average life of steel props varies from 10 to 13 years; whilst in the same pit it is not unusual to find that the life of a wooden prop, even when re-set time after time, and ultimately cut up for sprags and lids, does not exceed three months.

Electric coal-cutting machines have been largely adopted in recent years in seams of varying thicknesses and conditions. Considerable economy has arisen, both in the case of getting the coal and in the reduction of the proportion of small coal, consequent upon much of the holing being performed in the clunch or under-clay. The economy so effected may be roughly stated to vary from 3d. to 1s. per ton, according to circumstances.

The use of belts for conveying the coal along the working-face to the gate-ends has been successfully adopted in some thin seams, where the height is insufficient to permit of an ordinary tram being loaded.

Heading machines, by which as much as 108 feet of coal-heading per week has been cut, have also played an important part in the economical working of those thick seams where it is necessary to fore-win the coal, and for heading through shaft-pillars. These machines, which were until recently driven by compressed air generated on the surface, whereby great loss of power was involved by loss of heat and friction in the pipes, are now frequently actuated by electrically-driven portable high-speed compressors placed near to the machines and moved forward as the headings progress, thus avoiding the loss of a considerable amount of power in transmission, and providing a cheaper means of carrying the power to the machines.

The improvement in the surface mechanical equipment of collieries has been still more marked. The egg-ended boiler, with its accompanying steam-pressure seldom exceeding 50 or 60 pounds per square inch, and having evaporative powers of 200 to 300 gallons of water per hour and a duty frequently not exceeding 5 pounds of water per pound of fuel consumed, has given place to the Lancashire boiler, working at pressures varying from 100 to 160 pounds per square inch and having evaporative powers of 800 to 1,000 gallons and upwards per hour, whilst the duty may be roughly stated to be 8 to 9 pounds of water evaporated per pound of fuel consumed. In cases where the water has been found suitable, water-tube boilers, with working-pressures up to 200 pounds per square inch have been adopted to a considerable extent, with successful results, both as regards high evaporative power, economy in fuel, rapidity of steam-generation, and limitation of space. As an instance of the perfection to which the economical evaporation of steam may be brought, a Babcock-and-Wilcox boiler, fitted with a chain-grate stoker, a superheater and an economizer, gave an over-all efficiency of 88 per cent. compared with the efficiency of an ordinary Lancashire boiler, without an economizer or a superheater, of 60 to 65 per cent.

By the use of induced draught, high chimneys have, in some cases, been avoided, greater evaporative powers obtained from boilers, and inferior fuel consumed.

By the use of higher-pressure steam, coupled with more economically designed engines; by the greater use of expansion gear; and sometimes by superheating and condensing, the steam-consumption of modern collieries has been greatly reduced. Winding-engines, which formerly consumed 70 or 80 pounds of steam per indicated horsepower, may now be found using not more than 30 pounds of steam; whilst continuously-running engines and steam-turbines, such as are commonly used for fan and electric driving, are in some instances working with not more than 14 or 15 pounds of steam per indicated horsepower. The numerous smaller engines necessary in the past for driving screening-plants, workshops, shaft-pumps, and for other purposes, have been superseded in all modern collieries by the use of electric motors, thus avoiding long ranges of steam-pipes and the accompanying loss from radiation and condensation, which were visible at every colliery not many years ago.

As an instance of extreme economy in the production of power with inferior fuel, the plant erected by the Schwartzkopff Coal-dust Firing Syndicate, adjoining the Haydock collieries of Messrs. Richard Evans & Company, Limited, is well worthy of notice. The fuel, consisting of the finest dust produced on the colliery-screens and further ground in a mill to an impalpable powder, is introduced into the furnace of a water-tube boiler by means of a revolving brush, and is there consumed as a gas. The engines are of the triple-expansion high-speed type, condensing, and the steam is superheated to a high degree. The steam-consumption is said to be 9 pounds per indicated horsepower, and the duty of the boiler is 9 pounds of water evaporated per pound of fuel. Here is an instance of extremely low fuel and steam-consumption; but, on the other hand, the capital outlay and the cost of repairs to the mill, operate as a heavy counter-balance to the low fuel-cost.

Considerable attention has been paid by mining engineers of late years to the treatment of impure water to be used for boiler purposes. There is perhaps no greater necessity in connection with the working of a colliery than the provision of pure boiler-water, by which the fuel consumed and the labour, together with the cost of repairs, may be reduced to the lowest possible point. In view of the extremely low cost, which varies from ¾d. to 2d. per 1,000 gallons of water purified, it is somewhat astonishing to find that this easy source of economy is not more generally

adopted where bad water exists. Where sufficient condensing water is available, surface-condensing has been in many cases adopted, whereby the advantage of the use of pure boiler water, coupled with the economy of a vacuum, has given excellent results. Objection may be raised to the use of surface-condensers when the water forms considerable scale in the tubes; but this may, in many instances, be overcome by the occasional application of a weak solution of muriatic acid.

These various improvements have led to great economy in fuel, with the result that whereas the old-fashioned colliery (not being heavily watered) frequently consumed from 6 to 10 per cent. of its output in raising steam for the working of the colliery-engines, the well-designed colliery of recent date may be found to be working with a consumption as low as 2½ per cent. of the output.

An economy of such magnitude is not merely of vital importance to the colliery owner, but to the nation at large: for not only is the cost of production thereby decreased to an important extent, but the coal which, under the old practices, would have been wasted is preserved for the performance of useful work. When it is borne in mind that the annual output of coal in the United Kingdom has reached the enormous total of 251,000,000 tons, it is apparent that the coal-reserves of the country will be economized to an important degree when, in the course of years, the old-fashioned colliery machinery has been superseded by the more economical appliances adopted at modern collieries; for, an economy of 2½ per cent. only on the output of 1906 would represent no less than 6,275,000 tons of coal saved in one year.

In connection with this important subject, the better utilization of the calorific value of our fuels by the use of gas-producers and gas-engines has received and is receiving considerable attention. It is a well-known fact that the effective utilization of the calorific power of fuel by this means is about five times as great as when the same fuel is used under steam-boilers. The result obtained from plants of this description which have been running for many years, shows that a consumption of 1 pound of small coal or slack will produce 1 indicated horsepower in a gas-engine when running on full load; whereas the quantity of the same fuel used in a boiler for steam-raising would probably

be not less than 4 or 5 pounds, taking into account the losses by radiation and condensation. At a colliery in Yorkshire, a plant of this description has been provided for the purpose of utilizing the bats picked out at the screens. These bats, containing 18 per cent. of ash, yield 153,000 cubic feet of Mond gas per ton, having a calorific value of 145 British thermal units per cubic foot, and the waste-gases are used for heating the boilers of the colliery. The capital cost of a combined Mond producer, gas-engine and electric plant of 250 to 500 kilowatts may be taken approximately at £25 per kilowatt and the working cost at 0·4d. to 0·5d. per kilowatt-hour, including 10 per cent. for interest and depreciation on capital-outlay, and with fuel charged at 8s. 6d. per ton at the producers. In the case of plants of 1,000 kilowatts and upwards, working costs as low as 0·15d. per kilowatt have been obtained. The economy in fuel in such plants is admittedly great; but the additional capital-outlay, as compared with modern high-class steam-engines, detracts to a large extent from the apparent economy, necessitating careful consideration before deciding to depart from the use of the well-known and proved steam-engine. It need hardly be mentioned that the use of gas-engines will necessarily be confined to the supersession of engines other than winding-engines, except in those instances where the distribution of electric power to several winding-shafts may render the adoption of electric winding economical.

In those cases where the fuel is rich in nitrogen and of a non-coking character, the abstraction of the sulphate of ammonia and tar, plus the utilization of the surplus gases, may fully warrant the greater capital-outlay. Further, the result may, in the case of fuel of this character, not only be the production of the steam required for colliery purposes without the need of coal-firing; but, in addition, the possible sale of surplus gases and the revenue to be obtained from the sale of the bye-products. By the gas-producer, not only may the fullest calorific value be obtained from good coal, but waste-heaps, containing a large proportion of bituminous matter, will probably be more or less utilized in the future.

Suction-gas plants have made considerable headway in recent years. They may be very conveniently adapted to small isolated purposes and controlled by one man. The working cost of small plants of this class, inclusive of fuel (anthracite-nuts), stores,

labour and repairs, but exclusive of interest on capital and depreciation, may be taken to be about 0·2d. per indicated horse-power and the fuel-consumption at 1 pound per indicated horse-power. This is a great advance upon the results of the Cornish pump, the most economical of our old-fashioned engines, with a consumption of 3 to 4 pounds of good Welsh coal, and this result is hard to beat where large volumes of water require to be pumped from considerable depths. Various developments have been made in heavy pumping-engines of late years, but no marked economy in steam-consumption appears to have been gained in this class of engine.

The progress in coking and bye-product abstraction from the small fuel produced at many collieries has caused a far more valuable result to be obtained from fuel, which, not many years ago, was regarded as of little or no value. Thanks to our Continental neighbours, the beehive coke-oven is fast becoming extinct in favour of the retort-oven. The revolution which has taken place in this direction has not only been the means of utilizing, to a far greater extent than heretofore, a considerable proportion of our national wealth, but, at the same time, in many instances, has enabled collieries, the economic conditions of which rendered it difficult for them to exist in the past, to be transformed into profitable concerns, owing to the larger yield of coke per ton of fuel used, together with the value of the residuals, forming as they do, in many instances, a greater source of revenue than the coke itself. The objection originally raised to the use of retort-oven coke is rapidly dying out, and it is perhaps not going too far to say that with care on the part of the coke-burner as regards the percentage of water that he sends away in the coke, this objection will disappear altogether: for the reason that the density of retort-oven coke when properly burnt is generally greater than that of beehive coke, and it is consequently capable of carrying a heavier burden in the blast-furnace, a circumstance highly prized by the blast-furnace manager. The utilization of the surplus gas from regenerator-ovens forms another source of profit from this process, supplying, as it frequently does, power for driving electrical plants, and in some cases for the lighting of the colliery-premises and adjoining villages.

The careful consideration of economies in fuel for colliery-purposes becomes increasingly important, by reason of the greater depths from which the coal of the future will of necessity be wound. The question of raising large quantities of coal from depths of 2,500 to 3,000 feet, which will have to be confronted on a large scale at an early date, opens up a fresh field for the exercise of the ingenuity of the mining engineer. In the case of collieries sunk to such depths, where only one workable seam is available, very large areas, probably not less than 18 to 20 square miles to each pair of pits, will be necessary, to warrant the heavy capital-expenditure entailed in sinking and equipping plants of the magnitude that will be necessary to raise the large quantities of coal required to produce a low cost and enable a reasonable return to be made upon the large capital involved.

In order that large daily outputs may be raised from such depths, the winding-engines and the accompanying plant will necessarily require to be of great capacity and powerful construction, so as to withstand the strain of the heavy loads and rapid winding. The difficult question of the increasing weight of winding-ropes, to cope with the greatly augmented loads in deep shafts, will occupy much of the colliery manager's and the rope-maker's attention. The difficulty of providing a capel of equal breaking-strain to a rope of large diameter has fortunately been solved by the use of white metal run into the capel. The old method of capping, by means of hoops shrunk on to the cap, fails to give a resistance exceeding 75 or 80 tons, and this is obviously useless in the case of a rope with a breaking-strain of 150 to 200 tons. Loads of fully 25 to 30 tons will have to be lifted by one rope, if large outputs are to be obtained from the deep pits of the future, unless the expedient of winding in two lifts be adopted. Ropes of large diameter, composed of high tensile steel, will require to be used; and, with white-metal capping, there seems to be little fear of obtaining a capel equal to the breaking-strain of any rope which is likely to be put into use.

The question of the ventilation of the larger areas of workings, accompanying the more extensive mines of the future, and the greater volumes of air that will be required, will necessarily command the careful consideration of the mining engineer of

the future. Amongst other problems, it will be part of his business to decide whether it will be more economical and efficient to provide specially large air-ways or to adopt higher water-gauges. On the Continent, the practice has generally been followed of substituting high water-gauges for large airways. A good example of this appears in the case of the Neumühl colliery, where, I am informed, a Capell fan is producing 328,000 cubic feet of air per minute, at 15·8 inches of water-gauge, and an expenditure of over 1,000 horsepower in the steam-engine and 816 horsepower in the air. It appears to be highly improbable that such excessive water-gauges will be required in the mines of this country; but it is not improbable that higher water-gauges than those at present employed will be found to be more economical than the maintenance of great lengths of very large air-ways.

The improvement in screening-plants of late years has gone far to reach the point of perfection; and it is difficult to imagine that any great advance will be made in the methods of coal-sorting, except in the generalization of the practice of washing the smaller sizes of coal. In all new plants, where circumstances will permit, the screens will no doubt be placed at such a distance from the downcast-shaft as will render the impregnation of the intake-air with coal-dust from the screens practically impossible.

Before concluding this brief attempt to review the recent and prospective advancement in the engineering of collieries, it will be appropriate to say a few words with regard to the improvements which have taken place in the social condition of the miner during the past twenty-five years. In those days, colliery-cottages (many of which still remain) were frequently huddled together near the colliery, where they had little air-space surrounding them. The architect's skill and taste displayed in their design was not of a very high order, and the general effect was not calculated to arouse in the British miner and his family that respect for home which is conducive to cleanliness and respectability. The opportunities for obtaining rational recreation and mental improvement were few and far between, and the public-house not infrequently formed the only place where any kind of social intercourse could be procured. To-day, another

condition of things exists at nearly all modern collieries and at many old ones, where brighter and more picturesque houses, with ample air-space and gardens of a greater or lesser extent, are found to exist; houses which will enable the miner and his family to live a more healthy and brighter life than in the past.

Workmen's clubs or institutes, providing rational means of recreation and amusement, coupled with the opportunity of mental improvement by means of libraries and lectures, and the reading and discussion of papers relating to matters of interest to the working-man, are now to be found in connection with many old and new collieries. Such institutes afford a means of gradually improving the social life of the miner and those associated with colliery-work; and, if judiciously supervized by the resident colliery manager and his subordinates, can only result in a feeling of greater respect and confidence between the one and the other class. Whilst it may be said by some that this subject does not come within the category of mining engineering, it can hardly be argued that it does not form a very important part of the management of a colliery; for it is mainly by such consideration and attention that it may be possible to lift the miner to a social level commensurate with his intellect and his means.

In conclusion, I desire to thank you for the time which you have so kindly and patiently devoted to the hearing of this somewhat long, and I fear uninteresting, address.

Mr. Emerson Bainbridge, in moving a vote of thanks to the President for his interesting and excellent address, said that he had avoided superficial treatment in every department of mining, and had illustrated his address with figures which made it unusually practical. Mention had been made of the Trade Disputes and the Workmen's Compensation Acts, and there was also a wise reference to the danger of over-legislation for mines. The address was an interesting and practical summary of all that was involved in modern mining.

Prof. A. Lupton, M.P., in seconding the vote of thanks, said that the address embodied the results of great and carefully

gathered experience, and would be a guide for the younger members. He was particularly gratified at the reference to the reduction of the death-rate in mines, a matter in which The Institution of Mining Engineers had had a very considerable share.

The vote of thanks was cordially adopted, and was briefly acknowledged by the President.

The meeting then divided into two sections for the reading and discussion of papers. Mr. Maurice Deacon (president) presided over one section, and Mr. W. G. Phillips (vice-president) over the second section (in the rooms of the Royal Astronomical Society, Burlington House).

Mr. H. R. DE SALIS' paper on "Improvements required in Inland Navigation" was read as follows:—

IMPROVEMENTS REQUIRED IN INLAND NAVIGATION.

By HENRY RODOLPH DE SALIS, Assoc.M.Inst.C.E.

The author proposes, in the following paper, to record his views on the improvements required in inland navigation in this country, from the experience obtained from his association with Messrs. Fellows, Morton & Clayton, Limited, canal carriers, as a director for 10 years; and from having made a personal inspection of the whole of the inland navigations of England and Wales, amounting to a mileage travelled on waterways of over 14,000 miles, for the purpose of collecting the information contained in *Bradshaw's Canals and Navigable Rivers of England and Wales.**

In the first place, there often appears to be considerable uncertainty as to the extent of the navigable inland waterways of England and Wales, and more than once the author has heard the figures contained in the *Railway and Canal Traffic Act, 1888: Returns made to the Board of Trade in respect of the Canals and Navigations in the United Kingdom,* erroneously quoted as being a complete summary of the whole of them. This is far from being the case, although it is extremely difficult to define exactly what may be considered as "inland navigation."

The total mileage of the waterways described in the author's *Bradshaw's Canals and Navigable Rivers of England and Wales* amounts to 3,915 miles, comprizing 3,073 miles non-tidal and 842 miles tidal; and he considers that the above total is a fair representation. The Board of Trade returns for 1898 only show a total mileage for England and Wales of 3,167 miles, and do not apparently take into account amongst others such waterways as:—The river Arun; the river Avon (Bristol), the portion under the control of the Bristol Docks' Committee; the river Bure; the river Colne (Colchester); the Dartford and Crayford

* *Bradshaw's Canals and Navigable Rivers of England and Wales: A Handbook of Inland Navigation for Manufacturers, Merchants, Traders and Others,* compiled, after a personal survey of the whole of the waterways, by Mr. Henry Rodolph de Salis, 1904.

Navigation; the river Dee; the river Hull; the river Medway, Hawkwood to Sheerness, 21 miles; the river Mersey, Warrington to Liverpool, 25 miles; the river Ouse (Bedford), in respect of its direct course from Bedford to the sea, 75 miles, with the exception of $2\frac{3}{4}$ miles from St. Ives to Holywell; the river Parrett; the river Roding; the river Stour (Kent); the river Tamar; the river Tees; the river Teign; the river Thames, below London Bridge, including the navigation of Deptford, Bow, Barking and Rainham creeks; the river Trent, from Gainsborough to the mouth, 26 miles; the river Tyne; the river Waveney; the river Wye; and the river Yare.

FIG. 1.—STEAMER AND BUTTY-BOAT ON THE GRAND JUNCTION CANAL.

The navigable inland waterways of England and Wales may be divided, for the purpose of the more easy investigation of their condition, into two groups, the first consisting of the main system of connected waterways which have inland communication with each other; and the second consisting of isolated waterways, or small collections of isolated waterways, which have no inland communication with the main system. With regard to the waterways of this latter group, the author does not propose to say much. They comprize navigations of various sorts and

sizes and various degrees of prosperity and decay, and partake more of the nature of local concerns, destined to succeed or fail each on its own merits. The author would, however, suggest that, in considering any general scheme for the improvement of water-communication throughout the country, the question of extensions to connect some of these isolated groups of waterways with the main system might receive attention.

In considering the waterways of the first group, it will be apparent that the condition of each one affects the system of water-communication as a whole, and is, consequently, of primary

FIG. 2.—STEAM-LAUNCH "DRAGON-FLY," USED BY THE AUTHOR, IN WYRE LOCK, ON THE LOWER AVON NAVIGATION, WARWICKSHIRE.

importance to trade. The author is not a believer in canal-communication for rural or sparsely populated districts, but he considers that good water-communication between the principal manufacturing centres, the large towns, and the ports, is much to be desired.

Undoubtedly one of the principal causes which have operated to prevent the carrying out of improvements in the inland waterways of England and Wales by private enterprise is the excessive

number, as also the varied constitution, duties, interests, and procedure, of the numerous authorities controlling them. There are canal companies who are carriers, canal companies who are not carriers, railway companies, dock companies, boards of conservators, navigation trustees and commissioners, drainage trustees and commissioners, local authorities, private individuals, and, in some cases, no authority at all, in respect of portions of navigable waterways.

It is not surprising, therefore, that among so multifarious a collection of authorities charged with so many other duties, that the interests of navigation are not always, by any means, the first consideration. Hence it is that there has never been any serious movement amongst the proprietors of waterways towards their combining to form a united system of communication. There is no "Canal Clearing House," and (with few exceptions) every boat-owner has to deal separately with the management of every navigation over which he trades. Even among the independent canal companies forming the through routes, there is a great lack of united action; it is only since 1897 that the four canal companies, forming the route between London and Birmingham, have made arrangements by which through tolls can be quoted by the Grand Junction Canal Company, who own the largest portion of this route. Such matters as the arrangement of times for stopping the canal for repairs, ice-breaking, etc., are generally left to the individual action or inaction of each company.

FIG. 3. — COLUMN ERECTED IN ASHRIDGE PARK, HERTFORDSHIRE, "IN HONOUR OF FRANCIS, THIRD DUKE OF BRIDGEWATER, FATHER OF INLAND NAVIGATION," 1832.

Similarly, the ideas of different companies differ widely as to what constitutes efficient maintenance; one company will keep the channel of its canal fairly dredged, but will possibly neglect the towing-path so that it becomes a slough of mire in wet weather. Another company will attend carefully to the metalling and draining of its towing-path and the trimming of the hedges, but will allow the channel of the canal to choke with mud for want of dredging: this, being under water, cannot be seen, although it has a disastrous effect, by increasing the power required to haul the boats, and reducing their speed.

FIG. 4.—BASE OF THE BRIDGEWATER COLUMN, SHOWING THE INSCRIPTION.

If the number of canal companies were reduced, a considerable saving would be effected by the universal use of modern plant and machinery for executing repairs and dredging, the use of which is at present confined to the larger companies, such as the Manchester Ship, Grand Junction, North Staffordshire, and Leeds and Liverpool canals.

On the question of railway-owned canals, the author is of opinion that in general railway-ownership of canals is undesirable, as being inimical to canal-development; but he can hardly go so far as to endorse the sweeping assertion that all railways

desire to strangle the trade on the canals in their possession. In fact, the policy of railway companies towards the canals that they have acquired appears to have been, as might be expected, exactly what suits them best in each particular case, and consequently not always the most favourable to canals as a whole. One of the largest railway-owned properties, the Trent and Mersey canal of the North Staffordshire Railway Company, will compare favourably both in condition and in management with any independent canal. The Lancaster canal of the London and North Western Railway is equally well maintained, whilst among others which are quite up to the average may be mentioned the Ashton, Peak Forest, and Macclesfield canals of the Great Central Railway Company. On the other hand, a railway company having originally purchased a canal as the price of disarming opposition to its line, or of extinguishing a competitor, it is obvious that its policy with regard to it may not be one favourable to water-carriage or the adjoining canals. In several cases the obligations imposed by section 17 of the Railway and Canal Traffic Act of 1873, as regards maintenance in good working condition, appear to be a dead letter; but even if the Act is not openly violated, it is easy to discourage trade by such means as indifference to the requirements of the traders, the imposition of the full maximum tolls in all cases, and the ordering of frequent stoppages for repairs.

FIG. 5.—OLD PATTERN OF WOODEN DRAWBRIDGE, ON THE WILTS AND BERKS CANAL.

Years ago, Parliament permitted some extraordinary mutilations of canals by railways, two instances of which may be worthy

of mention. In 1879, the Monmouthshire Railway and Canal Company obtained an Act authorizing them to stop up and fill in the mouth of the Monmouthshire canal in the town of Newport, thereby severing communication between the Newport docks and the canal. In the following year, 1880, the canal was acquired by the Great Western Railway Company. In the returns made to the Board of Trade in respect of the canals and navigations in the United Kingdom for the years 1888 and 1898, it appears that the Monmouthshire canal was conducted at a loss by the Great Western Railway Company, and, under the circumstances, this is not surprising. In 1845, the Gravesend and Rochester Railway and Canal Company purchased the Thames and Medway canal, which extended from the Thames at Gravesend to the Medway at Rochester. The tunnel, which had previously conveyed the canal between Higham and Rochester, was turned into a railway tunnel, leaving the canal to extend from Gravesend to nowhere in particular.

Turning attention next to authorities controlling navigable rivers, it will be found that, in addition to navigation, they may have to consider the prevention of floods, the pollution of the stream, and the interests of rowing-boats, sailing-boats, house-boats, steam-launches, motor-launches, water-companies taking supplies from rivers, riparian owners, fishermen, bathers, etc. Sometimes authority is divided, as in the case of the Thames above Long Wittenham, where, in addition to the many duties carried out by the Thames Conservancy, the Thames Valley Drainage Commissioners have a separate drainage-jurisdiction; or, in the case of the Severn, where the towing-path between Gloucester and Worcester and again between Worcester and Stourport belongs to two distinct towing-path companies.

In earlier days, navigation was considerably hampered on many navigable rivers, by the control of the water exercised by mill-owners. Although many of these water-rights have been bought out, some still survive, as on the river Stour (Suffolk), and also on the river Stort, where a toll of 6d. for every vessel passing through a lock is payable to the occupier of the mill, in addition to the ordinary navigation-tolls. Again, in Somersetshire, Lincolnshire, and throughout the large group of waterways of the Bedford level and district, nearly all the waterways are

primarily maintained for the purpose of drainage, out of the rates levied on the land by various bodies of drainage commissioners, navigation being, consequently, quite of secondary importance. In the Bedford level, a large tract of country depends for its very existence on its waterways, into which the surface-water from the land is lifted by pumping-engines. In no other part of the country is there such a multiplication of authorities crowded together: tracing those in respect of the natural channel of the river Ouse from Bedford to the sea, they are as follows:—From Bedford to Holywell, 33½ miles, the navigation-rights are private property;

FIG. 6.—GRIFFIN'S LOCK, STROUD, ON THE THAMES AND SEVERN CANAL.

from Holywell to Earith, 5 miles, the river has no controlling authority, but the lock known as Brownshill or Over Staunch, situated in this length, is maintained by the South Level Drainage and Navigation Commissioners; from Earith to Pope's Corner, the junction with the river Cam, 11½ miles, and known as the Old West river, is dredged and kept open by the South Level Drainage and Navigation Commissioners, but the Bedford Level Corporation cut the weeds and are the owners of the lock at Earith called Hermitage sluice. From Pope's Corner through

Ely to Littleport Bridge, 9¼ miles, the river is under the jurisdiction of the South Level Drainage and Navigation Commissioners. From Littleport Bridge to ¼ mile above Denver sluice, 10 miles, the river has no controlling authority. From ¼ mile above Denver sluice to the commencement of the Eau Brink cut, 10 miles, the river is under the jurisdiction of the Denver Sluice Commissioners. Denver sluice was built by the Bedford Level Corporation, who own the site and appoint the sluice-keeper; the Denver Sluice Commissioners maintain the fabric of the sluice and all the sea-doors (gates), while the South Level Drainage and Navigation Commissioners maintain the navigation-doors (gates). From the commencement of the Eau Brink cut to its termination, 3 miles, the river is under the jurisdiction of the Conservators of the Ouse Outfall. From the termination of the Eau Brink cut to the mouth of the river, about 4 miles further, the jurisdiction is that of the King's Lynn Conservators. Again, the haling-ways (towing-paths) between Denver sluice and King's Lynn are under the jurisdiction of the Ouse Haling-ways Commissioners; and the banks of the river between Denver sluice and the commencement of the Eau Brink cut are under the jurisdiction of the Ouse Banks Commissioners, and are divided into six districts. It is interesting to note that, throughout the Bedford level, doubtless on account of the Dutch origin of the works of drainage, in matters relating to inland navigation the district appears almost as a foreign country. Not only are the boats (called fen-lighters) and the method of working them chained together peculiar to the district, but in addition there exists an almost entirely different vocabulary of terms respecting river and canal navigation from that used in any other part of the country.

Having now rapidly reviewed the controlling authorities in respect of the navigable waterways of England and Wales, the author submits that one of the first steps to be taken in the direction of reform is to reduce greatly their number, and to deprive of all navigation-jurisdiction those authorities that are adverse or indifferent to the development of navigation. The author thinks it desirable that the State should control such of the waterways as could be made useful, or, say for instance, the main routes, leaving branches and feeders as at present, so that long-distance traffic might be administered by one authority.

Passing on to consider the present condition of the waterways of England and Wales, the author will examine that of the main system of connected waterways. There is nothing in it approaching the uniformity possessed by the railway system with its universal gauge, interchangeable rolling stock, and arrangements for forwarding and receiving traffic to and from the lines of other companies. The waterways differ widely in character, and may be arranged in three principal classes as follows:—

(1) Canals, being waterways constructed solely for the purpose of conducting traffic, and affording still water for the passage

FIG. 7.—LANCASTER AQUEDUCT, OVER THE RIVER LUNE, ON THE LANCASTER CANAL OF THE LONDON AND NORTH-WESTERN RAILWAY COMPANY.

of craft in either direction. Setting aside, for the moment, the Manchester, Gloucester and Berkeley, and Exeter ship-canals, the gauge of the canals varies from that of narrow-boat canals, admitting narrow boats measuring 72 feet in length and 7 feet beam, with a draught varying from 2 feet 6 inches to 4 feet, up to that of the Aire and Calder navigation, and the newly constructed Aire and Calder, and Sheffield and South Yorkshire junction canals, which have locks giving a capacity of 120 feet by 17 feet, and a draught of water of 7 feet 6 inches.

(2) Upland rivers made navigable by the provision of locks and weirs, which have, usually, a stream flowing downwards with a velocity, say, up to 3 to 4 miles an hour. As in the case of the canals, the gauge of the locks of the upland rivers varies considerably. The river Soar, which forms for the most part the Leicester and Loughborough navigations, admits craft measuring 72 feet in length and 14 feet beam, with a draught of 3 feet 6 inches, while the locks of the river Weaver measure 229 feet in length and 42 feet 6 inches in width, and will admit, at one time, four vessels of the ordinary type using the river: these are 90 feet long, 21 feet beam, and draw 10 feet 5 inches of water.

FIG. 8.—BEARLEY AQUEDUCT, ON THE STRATFORD CANAL OF THE GREAT WESTERN RAILWAY COMPANY.

(3) Tidal rivers and estuaries, where rough water is at times encountered, and where the tide ebbs and flows often with a considerable velocity, which may, as in the case of the Severn estuary, amount to as much as 12 knots an hour on spring tides.

As almost all through routes between important centres at the present time contain links of narrow canal, the effect of these diversities of gauge is to confine any long-distance through traffic to narrow boats. Nothing but a narrow boat can navigate

between London and Northampton, Leicester, Nottingham, or Manchester, and nothing but a narrow boat can get into or out of Birmingham. If an attempt be made to take a narrow boat from London to Leeds, it will fail altogether, as it will be stopped at either Wigan, Sowerby Bridge, or Cooper Bridge by the locks of the Leeds and Liverpool canal, or Calder and Hebble navigation, which, although of twice the width required by the narrow boat, are 10 feet too short. Again, the narrow boat occasions a large amount of transhipment, as it is not safe to send it on wide estuaries or tidal waters. When goods are to be sent from London to Liverpool direct, narrow boats to load them cannot be sent lower down the Thames than Greenwich, and even then they will have to be fastened two together, side by side, for stability. When the boats arrive at either Runcorn or Ellesmere Port, the cargo will have to be transhipped into flats, as under no circumstances is it safe to send them down the Mersey estuary. Similarly, a narrow boat cannot be sent from London to Hull, as it is not fit to go below Stockwith on the river Trent, or on the river Humber. In the case of cargo in Leeds for delivery in London, the author will presume that it starts from Leeds in a short boat measuring 57 feet 6 inches in length and 14 feet beam. It can proceed by way of Castleford, Wakefield, Sowerby Bridge, Rochdale, Manchester, Runcorn and Ellesmere Port to Chester on the Shropshire Union canal, where it will be stopped by the insufficient width of the locks; and, for the same reason, if it travels by the river Weaver and the Trent and Mersey canal of the North Staffordshire Railway Company, it cannot proceed further south than Middlewich. Again, seeking to reach its destination by another route, it can journey by Wakefield, Barnsley, Doncaster, Keadby, Newark, Nottingham, Loughborough and Leicester as far as the flight of seven locks at Watford (Northamptonshire) on the Grand Junction canal, where it would be again stopped. These locks can only accommodate narrow boats, and form the sole remaining obstacle to prevent the boat from reaching London.

Supposing that the author wished to take a cargo from Birmingham to King's Lynn, he would reach Peterborough with his narrow boat without difficulty, at any rate so far as the gauge of the navigations is concerned. At Peterborough, he would be unable to follow the direct route by entering the Middle level,

as the entrance-lock, called Stanground sluice, is too short, and it would be necessary for him to travel *vid* Wisbech to the Ouse at Salter's Lode. This, as again the locks at Wisbech and Salter's Lode are too short, he could only do by waiting at Wisbech for a spring tide to level the water in the river Nene with that of the Wisbech canal, and also at Salter's Lode for another spring tide to level the water in the river Ouse with that of Well creek. Yet another difficulty of a different nature will present itself on this journey, for the horse which the author had brought

FIG. 9.—HINCASTER TUNNEL, ON THE LANCASTER CANAL OF THE LONDON AND NORTH-WESTERN RAILWAY COMPANY.

from Birmingham to tow his boat will be useless in the Fen country, as he cannot jump. In the Bedford level and district, gates are not placed at the points where the towing-path passes through the various boundary-fences, but stiles (some of them as high as 2 feet 7 inches) are provided instead. All towing horses have to jump these stiles and frequently give themselves nasty knocks in so doing.

Seeing that a barge of 60 tons only takes the same crew and practically only the same power to haul in a good waterway as a narrow boat, of the same length, but of half the width and

between London and Northampton, Leicester, Nottingham, or Manchester, and nothing but a narrow boat can get into or out of Birmingham. If an attempt be made to take a narrow boat from London to Leeds, it will fail altogether, as it will be stopped at either Wigan, Sowerby Bridge, or Cooper Bridge by the locks of the Leeds and Liverpool canal, or Calder and Hebble navigation, which, although of twice the width required by the narrow boat, are 10 feet too short. Again, the narrow boat occasions a large amount of transhipment, as it is not safe to send it on wide estuaries or tidal waters. When goods are to be sent from London to Liverpool direct, narrow boats to load them cannot be sent lower down the Thames than Greenwich, and even then they will have to be fastened two together, side by side, for stability. When the boats arrive at either Runcorn or Ellesmere Port, the cargo will have to be transhipped into flats, as under no circumstances is it safe to send them down the Mersey estuary. Similarly, a narrow boat cannot be sent from London to Hull, as it is not fit to go below Stockwith on the river Trent, or on the river Humber. In the case of cargo in Leeds for delivery in London, the author will presume that it starts from Leeds in a short boat measuring 57 feet 6 inches in length and 14 feet beam. It can proceed by way of Castleford, Wakefield, Sowerby Bridge, Rochdale, Manchester, Runcorn and Ellesmere Port to Chester on the Shropshire Union canal, where it will be stopped by the insufficient width of the locks; and, for the same reason, if it travels by the river Weaver and the Trent and Mersey canal of the North Staffordshire Railway Company, it cannot proceed further south than Middlewich. Again, seeking to reach its destination by another route, it can journey by Wakefield, Barnsley, Doncaster, Keadby, Newark, Nottingham, Loughborough and Leicester as far as the flight of seven locks at Watford (Northamptonshire) on the Grand Junction canal, where it would be again stopped. These locks can only accommodate narrow boats, and form the sole remaining obstacle to prevent the boat from reaching London.

Supposing that the author wished to take a cargo from Birmingham to King's Lynn, he would reach Peterborough with his narrow boat without difficulty, at any rate so far as the gauge of the navigations is concerned. At Peterborough, he would be unable to follow the direct route by entering the Middle level,

as the entrance-lock, called Stanground sluice, is too short, and it would be necessary for him to travel *viâ* Wisbech to the Ouse at Salter's Lode. This, as again the locks at Wisbech and Salter's Lode are too short, he could only do by waiting at Wisbech for a spring tide to level the water in the river Nene with that of the Wisbech canal, and also at Salter's Lode for another spring tide to level the water in the river Ouse with that of Well creek. Yet another difficulty of a different nature will present itself on this journey, for the horse which the author had brought

FIG. 9.—HINCASTER TUNNEL, ON THE LANCASTER CANAL OF THE LONDON AND NORTH-WESTERN RAILWAY COMPANY.

from Birmingham to tow his boat will be useless in the Fen country, as he cannot jump. In the Bedford level and district, gates are not placed at the points where the towing-path passes through the various boundary-fences, but stiles (some of them as high as 2 feet 7 inches) are provided instead. All towing horses have to jump these stiles and frequently give themselves nasty knocks in so doing.

Seeing that a barge of 60 tons only takes the same crew and practically only the same power to haul in a good waterway as a narrow boat, of the same length, but of half the width and

capacity, and that the barge of 60 tons is sufficiently seaworthy for all ordinary estuary work, the author considers that this vessel would form the best minimum unit to which all alterations for the purpose of standardizing British waterways should be worked. This would also accord with the case of any branch narrow-boat canals at present existing, and not thought worthy of any capital-expenditure, as two narrow boats are the exact equivalent in a lock of a barge of 60 tons. For the most important main lines of canal, the author would suggest locks with a capacity of at least three barges of 60 tons, in which case the locks should be divided again by a third intermediate pair of gates, so that a lock for one, two, or three barges could be readily made. The average top width of a narrow-boat canal is 40 feet; but a very small proportion of this width is available for loaded boats, on account of the flat shelving slope to which the banks are usually formed. If these slopes were taken out and the canal deepened and walled on both sides, no extra width of land would be required to make a narrow-boat canal available for barges of 60 tons.

Concerning mechanical haulage on canals, a certain amount has from time to time been written. By some persons, it would appear to be regarded as a panacea for all the ills of canals in their present condition, and not long ago a daily paper made the startling announcement of a "report that mechanical haulage was about to be practically tested for canal traffic." Mechanical haulage by steam-boat has been known on canals for upwards of one hundred years, but it has never greatly developed on account of the smaller canals being so badly adapted for its use, just as the heaviest type of modern locomotive would be quite unsuitable for work on the original permanent way of one of the early railways.

The advantages sought to be obtained by any system of mechanical haulage are obviously greater speed and greater loads than those taken by horses; and, as a large proportion of the through routes in this country contain narrow-boat canals, it will be well to examine particularly the question of haulage as applied to them. Contrary to what is often supposed, haulage by steam or other form of motor-boat on ordinary narrow canals, adds but little to the speed of vessels as compared with horse-haulage. Whatever horsepower may be developed, the rate of

progress is limited by the ease with which the water in the canal can get past the vessel as it travels: this is governed by the proportion of the cross-section of the waterway to the immersed section of the vessel, subject to the proviso that with a given immersed section of vessel and a given section of waterway, the waterway which has the most water beneath the vessel, and the sides of which more closely approximate to the vertical, will give the best result. Any attempt to increase the speed beyond what the section of the waterway permits, merely causes a waste of

FIG. 10.—PERSHORE NAVIGATION-WEIR, ON THE LOWER AVON NAVIGATION, WARWICKSHIRE.

power, heaps up the water in front of the vessel, creates a breaking wave highly injurious to the banks of the canal, and renders the vessel more difficult to steer. And further, it is not practicable on the general run of narrow-boat canals to gain any advantage by making use of mechanical haulage to tow a train of boats. Long pounds of water are the exception and not the rule, and at every lock each boat has to be locked through separately, so that in the case of a train of five boats the delay at each lock will be at least five times as great as in the case of a single boat. Again, if the working of boats in trains were universal on narrow canals,

delay and inconvenience would be constantly caused by the abstraction of sundry locks of water from the short pounds at one time, without any corresponding replenishment from the pound above, thereby causing, temporarily, a serious reduction of the navigable depth.

The author's company own 20 narrow steam-boats, and nearly all of them are engaged in the London and Birmingham traffic. They measure 71 feet in length by 7 feet beam, and draw 3 feet 6 inches of water when loaded. Owing to the space occupied by the machinery, these boats only carry about 17 tons instead of from 28 to 30 tons, the load of an ordinary narrow boat, and consequently they always have to work towing one narrow boat behind them. On the Grand Junction canal, where the locks are large enough to accommodate the two boats at one time, this works well enough; but, when passing over the Warwick and Napton, and Warwick and Birmingham canals, where the locks are narrow, delay is occasioned by each boat having to be locked separately at every lock. The author is of opinion, therefore, that before mechanical haulage can come into general use on the waterways of England, the channels of the narrow canals must be improved so as to permit of greater speed, and the capacity of the locks must be enlarged so as to accommodate a suitable train of boats at one time.

Passing from the steam-engine to consider the modern motors available for propelling canal-boats, the author may say that he has not yet seen any internal-combustion engine which he considers sufficiently reliable for the ordinary everyday work of through traffic. On the question of safety alone, he could not advise the use of any motor requiring petrol to work regularly through tunnels. The chance of a petrol-fire in a long tunnel, which might easily at the same time contain a tow of over 20 boats having upwards of 50 people on board, is not lightly to be risked. The danger of such liquids, giving off inflammable vapour at ordinary temperature, has been only too well demonstrated by the explosion on the Regent's canal of October 2nd, 1874, and, although the great amount of damage done was caused by gunpowder, it no doubt owed its origin to leaky benzoline or naphtha casks. The use of petroleum or paraffin oil for working motors in boats has the advantage over petrol in regard to risk of accident from inflammability; but it is not per-

missible on vessels carrying damageable cargo, on account of the all-pervading and most penetrating smell given off by it. The writer has lately inspected the wooden hull of a canal tug-boat from which a petroleum-engine had been removed after a few months' work in order to give place to a steam-engine, and although the engine and the top and sides of the engine-room down to the gunwale had been removed for some days, the odour of petroleum arising from it was most pungent. Of all types of internal-combustion engine, the author considers the suction gas-engine open to the least number of objections for use for canal-boat propulsion; but it has yet to prove its ability to keep time with steam on long journeys.

The most desirable motor of all for the purpose would doubtless be an electric motor driven by storage batteries, to be exchanged for others freshly charged as required at different points on the canal, but such a system must of necessity await the invention of an accumulator of less weight and size, and costing less to maintain, than any that are on the market at the present time.

The author may briefly recapitulate his views as follows:—He is of opinion that, when the waterways which it is considered desirable to improve have been selected, the first step should be to re-organize the authorities controlling them; and that, when the works of improvement have been carried out and efficient waterways provided, the problem of mechanical haulage will soon solve itself.

The PRESIDENT (Mr. Maurice Deacon) said that Mr. de Salis, in his paper, had discussed an extremely interesting subject, very largely from a commercial point of view; and, as it was particularly interesting to the colliery-owner, he thought that it should claim their attention and consideration. Railway companies were large owners of canals, and the owner of a small section might prohibit the utilization of the adjacent waterways to any useful effect. Mr. de Salis had pointed out that it was useless to hope for reasonably cheap water-carriage on through routes, until the whole of the innumerable canal companies, which occupied the waterways, could be either induced to amalgamate, or to sell

their undertakings to a single proprietor. Some years ago an attempt was made to amalgamate the several canals connecting the Midland coal-fields with London, but one or two of the canal companies did not approve of the proposed scheme of amalgamation, which, from accurate calculations, would have enabled coal to be carried from the Midland coal-fields to London for 5s. per ton instead of the 6s. 6d. then paid to the railway companies. The difficulty, with regard to passing through small locks, might be overcome by fitting the boat with wheels, and running it over a railway, of the required gauge, laid at the side of the lock.

Mr. W. Price Abell said that he was surprised that canals continued to exist under the vexatious obstructions to their intercommunication. If the authorities would undertake the nationalization of canals, greater good would ensue than from the proposed nationalization of railways.

Mr. Frank Rayner (River Trent Navigation) said that Mr. de Salis had had an unique experience of the waterways of England in regard to their works, natural features and trades. The River Trent Navigation, with which he (Mr. Rayner) was associated, were carriers, as well as owners of navigation rights, and unfortunately they knew the great difficulties which arose from the multiplicity of companies and authorities that had control over the inland waterways. There was absolutely no justification, so far as efficiency was concerned, for the continued existence of these innumerable bodies. In the case of the Bedford level and adjoining navigations, nine distinct authorities controlled a length of about 86 miles; and, in the case of two short navigations, there was no controlling authority. Consequently, there was no uniformity, and this led to endless confusion and difficulty. His own view was that the country should be divided into natural districts, following the great watersheds of the country, that each watershed should be entrusted to a board of management, and that a central authority should be responsible for ensuring uniformity of gauge, conditions and maintenance, and that the works and control of the boards of management were consistent with each other. He agreed with Mr. de Salis in giving a word of commendation to some of the railway companies who did their duty to their canals; but they were in the minority, and there was endless

difficulty in conveying traffic over waterways controlled by railway companies. Independently-owned canals welcomed mechanical traction; he thought that, so long as a proper speed was not exceeded, it was desirable, and it kept down weeds: but railway companies alleged that it would burst the banks. In one railway-owned canal, the banks would withstand the pressure of pleasure steamboats, but when cargo was conveyed instead of passengers, the use of steamboats was said to be dangerous and was prohibited. Independently-owned canals did not raise artificial difficulties, but many railway companies, on the contrary, would not keep their canals open by such measures as breaking the ice in winter: they said that those who paid the tolls should provide horses; and they placed other obstacles in the way of traffic. A flagrant case existed of a railway-controlled canal, which before the railway-days had perhaps hundreds of thousands of tons passing over it, but now the water-supply was said to be insufficient for a small fraction of the traffic. There should be a minimum barge, to which all alterations for standardizing waterways should be designed, but the question of a standard canal or a standard barge should not be rigidly enforced. Where natural conditions admitted, that minimum should be multiplied as much as possible, and if a barge carrying 60 tons was found to be a practical minimum, then, as in the case of the River Trent Navigation, where the water-supply and other natural features enabled them to do so, that minimum might be multiplied and trains of barges might be passed through the locks at once. It should be borne in mind that when a certain tonnage, with a tug or other propelling power, was exceeded, practically all the freight earned by the additional tonnage was profit. The cost of towing 60 or towing 70 tons was practically the same, assuming that the waterway was in a proper condition. He agreed that, with improved organization and waterways, and mechanical means of propulsion, a large traffic would follow.

Mr. L. F. Vernon-Harcourt said that Mr. de Salis had shown plainly the difficulties which, at present, confronted conveyance on through routes. The question of the length of canals and navigable waterways was not a very important matter, but it was curious that the figures contained in the first report of the Royal Commission on Canals did not agree with those approved by

the Board of Trade. He looked forward with great interest to the final report of the Royal Commission on Canals, which might be issued before the close of the present year. The Royal Commissioners had inspected canals in Belgium, France and Germany; but, on Continental waterways, the conditions were very different from what they were in this country. In Germany, barges, carrying up to 1,000 or 1,200 tons, could be used on the large navigable rivers; the standard barge, on French waterways, carried 300 tons; and, in Belgium, the standard barge carried 400 tons. Despite the improvements carried out on French waterways, the bulk of the traffic was conveyed on the waterways going into Belgium, from the northern coal-fields, and along the river Seine; and, in the south of France, there was very little traffic, even over the waterway, originally made as a ship-canal, connecting the Mediterranean with the Bay of Biscay, and on most of the other central and southern waterways, notwithstanding the improvement of these waterways, making all the main canals of a uniform gauge for barges carrying 300 tons. Through-route waterways should be placed under one control. Mr. Rayner had mentioned the possibility of grouping them according to the drainage-areas; and, so far as rivers were concerned, that would be desirable, if Britain had such great rivers as they had on the Continent. It was desirable to group the rivers according to the basins; but if they dealt with canals in that way, they would find that most of the canals from the centres of trade to the various ports passed through several river-basins, and a large number of locks would be required. Mr. J. A. Saner, in a paper read before the Institution of Civil Engineers early last year, proposed the creation of a number of through routes;* but it was necessary to provide through routes of sufficient size, and to raise money for that purpose. Although it was desirable that the separate authorities should be abolished, it was not easy to induce them to give up whatever rights they might possess. He approved of the creation of certain through routes, and in a paper,† read before this Institution at Birmingham, a few years ago, he pointed out that a route from Birmingham to

* "On Waterways in Great Britain," by Mr. John Arthur Saner, *Minutes of Proceedings of The Institution of Civil Engineers*, 1905, vol. clxiii., page 21 and plates i., ii. and iii.

† "Inland Navigation, with Special Reference to the Birmingham District," by Mr. L. F. Vernon-Harcourt, *Trans. Inst. M. E.*, 1895, vol. viii., page 511.

the sea by Worcester and the river Severn would probably prove useful and profitable. Routes, however, say, from Birmingham to the Mersey, to the Humber, or to London, would have to cross a number of water-partings, which made it extremely expensive to construct a satisfactory waterway. He agreed with Mr. de Salis that if through waterways were provided, haulage would not prove an insurmountable difficulty. The financial difficulties encountered during the construction of the Manchester ship-canal, a waterway for ocean-going vessels, had deterred people, more than one would wish, from undertaking schemes for the improvement of inland waterways. In the meantime they should wait for the decisive report of the Royal Commission on Canals, who might formulate a scheme, other than for the purchase of the canals by the State; because he did not think that would be a practical scheme, or one that a government should undertake.

Mr. Gordon Thomas (Grand Junction Canal) said that Mr. de Salis' paper might be taken as correctly representing the great difficulties met with by the trader who required to navigate upon a canal. Traders were now in the hands of the railway companies, and he asked whether the companies served mine-owners conveniently and at such rates as enabled them to compete, say, with Continental and other competitors. From his own knowledge and from the evidence that had been given before the Royal Commission on Canals, it appeared to him that traders were not satisfied. Consequently, with the difficulties at present existing, he asked whether the canals could be so improved at a reasonable expenditure as to enable colliery owners to be placed in a better position. He had hoped that Mr. de Salis would have stated the speeds and relative costs of hauling by the several systems employed by his firm, as compared with railways; and what the costs would be with an improved canal, such as he had suggested, taking barges of 60 tons. Personally, he was rather in favour of a load of 80 tons, by reason that the present narrow boat could carry 40 tons, and it was merely putting the maximum load in pairs through one lock. A load of 80 tons seemed convenient, and it could be hauled through the improved canal at the same rate as a load of 60 tons; and, therefore, a load of 80 tons in one vessel could be taken from the country (especially if taken in trains of three) in improved canals and improved lockage at

possibly one-half of the present rate, say, only 0·442d. per ton per mile. Taking any district, say, Staffordshire to London, the rate was 7s. per ton; and on the improved canal, under improved conditions, the rate would be reduced to 3s. 3d: that would be an enormous advantage to the country, and it would require no heroic system of ship-canals carrying vessels of 1,000 tons. The speed of the steamers and butty-boats worked by Messrs. Fellows, Morton and Clayton, Limited, was, on a level pond, 3½ miles per hour; but that speed was reduced (owing to various reasons) for through traffic, say from London to Birmingham, a distance of 135 miles, to 2·15 miles per hour. On that route, the traffic passed through 157 locks, occupying 14 hours 54 minutes; and, in addition, 9½ hours were lost through slowing down when approaching bridge-holes. Consequently, about 24½ hours were lost by blocks in the waterway, which might, with improved conditions, be entirely abolished. One of the greatest difficulties in improving or maintaining canals was the water-supply. The present locks were of antiquated construction, and an improved system of lockage would have to be adopted. At the present time there was nothing more efficient than inclined planes or vertical lifts, which could be constructed at much less cost than a flight of locks. In addition, they saved time, and their capacity for passing traffic was almost unlimited. The whole of the bridges, throughout the length of any main canal, would also require reconstruction. The proper sectional area of a canal should not be a wide canal with a big surface-area exposed to evaporation and leakage, but a section approaching a rectangular form, with a depth at least one-half greater than the draught of the vessels frequenting it. These dimensions would allow a much greater speed than at present, and the cost of maintenance of the paths, banks and dredging would be reduced. A canal, 45 feet wide and 7 feet deep, would take craft with a capacity of 80 tons; and it could be constructed, to connect the four waterways of England, at a moderate cost, requiring the purchase of very little land, and with little disturbance of important works on the banks of the canals. Improvements had not been carried out, owing to the past action of Parliament, particularly in 1846, in permitting railways to control certain links. The Grand Junction canal was hemmed in, owing to a policy which nobody could blame Parliament for having followed, for they all liked to

experiment; but, when they found how detrimental it was to the progress of the canals, it was not flattering to our commonsense that they should have allowed it to continue for so many years. The Grand Junction Canal Company tried in 1853 to bring about a large amalgamation, but they were stopped by railway-owned links. They now owned or had leased 171 out of 180 miles of the route from the Nottingham and Derbyshire districts to London; but the last few miles were in the hands of a railway company. The maximum craft only carried about 22 tons, and frequently that load was reduced to 10 and 12 tons, so that it was absolutely impossible for traffic to be brought profitably from such a distance. Large sums of money had been spent in endeavouring to develop the traffic on that route, but they had failed owing to the fact that a few miles belonged to a railway company, which had been quite contented to leave the canal in the state in which it was handed over to them in 1846. As the independent and isolated canals could not possibly bring about any development, this must be effected by a stronger body. He anticipated that the Royal Commission on Canals would express an opinion as to the type of canal that should be provided. In 1895, at the Birmingham meeting of the Institution of Mining Engineers, some able papers were read, but the proceedings did not contain any recommendation as to the views of the members on the subject, which was of such great importance to the coal trade.

Mr. P. Bonthron (London) wrote, as one associated with lighterage matters, and who had traversed nearly every canal and canalized river south of the Midlands, that he had come to the conclusions that: (1) Large or ship-canals should be encouraged. (2) Canals within a radius, say, of 20 miles of a port, even as they are now existing could be made profitable; and dock or landing and railway-charges would be thereby avoided, and a saving effected. (3) Unless the existing inland canals are developed, and the uncertainties of the water-difficulty overcome, they cannot compete with railways. (4) In all the discussions of the canal-question, a very important point and factor had been quite overlooked, and that was the labour-question. Should any development take place, the wages of the canal-boatmen might have to be considered, and any advance of their present wages would seriously hamper the industry. Thames lightermen, he

possibly one-half of the present rate, say, c... per mile. Taking any district, say, Staff... rate was 7s. per ton; and on the impr... conditions, the rate would be red... an enormous advantage to th... heroic system of ship-canal... speed of the steamers and ... Morton and Clayton, L... hour; but that spee... through traffic, sa... 135 miles, to 2... passed throug... in addition ... approachi... lost by ... conditi... in im... pre... sy... t...

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Mr. OWEN J. LLEWELLYN (H.M. Inspector under the Canal Boats Acts) wrote that the main point in dealing with inland navigation was to remember that England was quite differently situated from all other countries. France, Belgium and Germany were all continually being urged as models to copy, and England was represented as being far behind them with regard to inter-communication. But the advocates of new and improved canals should remember that Hull, London, Bristol, Liverpool, Glasgow, and scores of other large towns were connected by the sea. And Manchester, Gloucester and other places, by reason of their ship-canals, could also be included. Therefore, with the exception of Birmingham, the Potteries and the Black Country of Staffordshire, there was hardly a manufacturing district of importance which was not within 20 miles of a sea-connected port.

The modern practice also of motor-traction, direct from works to dock-side, was a serious and growing competitor to canal-traffic; and it was only an unpractical visionary who would propose to use the taxpayers' money to support a system which had failed simply because of the competition of more modern and up-to-date methods of transit. When canals were in their hey-day, the alarmed road-authorities eased the gradients of some of their roads and laid down setts to compete with them. This had little effect, and canals continued to be extended. But as canals had beaten roads, so railways had beaten canals, and it was well known that canal companies were only too pleased to find anyone to take over their decaying businesses; at the same time, the railway companies grasped at the idea of getting rid of

their only possible competitors. The story of the North Stafford-shire Railway Company, as told to him, makes this clear: When the directors of the Canal Company saw that railways were doing elsewhere, they made a railway alongside of the canal, and guaranteed the canal shareholders against loss. The result had been satisfactory from a business point of view, although the absence of competition had prevented any cutting of rates and so naturally displeased certain traders.

His (Mr. Llewellyn's) work took him all over England and Wales, wherever there was any navigable water, and he divided canals into two distinct kinds:—(1) Where there would be water in any case; and (2) where there would not be water, unless it was artificially introduced. He thought that if successful foreign canals were considered, it would be found that very seldom were they anything but canalized rivers, or, at any rate, canals in flat districts. Of course, two rivers might be joined by a connecting artificial canal, although this was exceptional. English canals, as a rule, were entirely artificial and the number of locks was very much greater than on the Continent. Extra locks not only entail extra cost, but they considerably shorten the lives of the boats. He was often amused by motorists who desired to turn canals into speed-ways, as if canals lay as straight from town to town as railways do. The reverse was the case and, out of flat land, the canal followed the contour of the country until the distance was often doubled.

He agreed with Mr. de Salis in his opinion that rural or sparsely populated districts did not need intercommunication; and farmers had little to sell or buy now-a-days.

It was impossible to augment speed on canals by engines, for it was well known that two donkeys could pull a laden boat as far as a team of big horses. Any increase in pace piled the water in front and dropped the stern of the boat on the bottom of the waterway.

Because of late years there had been no very long frost, it had been forgotten that such had ever occurred; but a total stoppage of water-traction for nine weeks (as had frequently happened) would play havoc with an artificially-fostered big industry. A week's delay even now produced a great deal of suffering among the boat-people.

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might mention, now received such wages that, with the existing rates received for the lighterage of goods, this class of business was more or less unremunerative. (5) He agreed with Mr. Gordon Thomas (Grand Junction Canal) as to the size of barges to be used on certain canals, and as to the suggested widening of the locks so as to allow of the passage of craft carrying 80 tons: this could be done without great expense. Personally, he advocated the use of an even larger size of barge, if the depth of water so permitted. In conclusion, he considered that Mr. de Salis' paper was a very sound production; it formed a good basis for future development, and it was written by a gentleman who had very wide experience relating to these matters.

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them) would be great, and if to this were added the cost of enlarging locks and deepening channels in order to make all canals take a bigger size of boats, it would be difficult even for a company-promoter to issue a favourable prospectus. Further, until the last canal was finished in the new style, intercommunication would not be possible: there would be a record lock-up of capital.

He felt rather like Balaam must have felt; but, with his opportunities of seeing canal-traffic, he would be blind if he could see (much as he should like to) any chance of success in the resurrection of canals; and very few people seemed to take any interest in the subject.

He trusted it would be understood that, officially, he had nothing to do with canals—only with canal-boats and their inmates. Neither was he an engineer or expert, but as he had said in his evidence before the Royal Commission on Canals—he would be very dense if he did not keep his eyes open with regard to the surroundings of his work.

In conclusion, he asked the question as to who was going to pay for the proposed enlargement of the canals? And engineers seemed to be the only class who would make anything out of it.

Mr. Arthur Carey (Widnes) wrote that Mr. de Salis' paper was a powerful and practical appeal, from a practical man who knew England's waterways as probably no other man knew them. There could be no doubt that manufacturers in this country suffered severely from the high cost of transport. If the cost of transport in this country were as low as it actually was at the present time in Belgium and Germany, chemical products would be cheaper to produce by about 10 per cent. of their sale-price. This figure had been carefully calculated, and was the conclusion deduced from data collected by the Internal Transport Committee of the Society of Chemical Industry. The points to which Mr. de Salis had drawn the greatest attention were undoubtedly the key to the situation: (1) The necessity for uniformity of gauge on the main through routes, and a material increase in that gauge. From his own experience, he would go further than Mr. de Salis and ask for waterways capable of taking barges carrying cargoes of 100 tons; and, even then, the barges would be far short of the average barge, carrying 200 to 300 tons, used on Continental canals. (2) Mr. de Salis drew attention to the multitude of

small authorities, controlling short lengths of water, thus adding greatly to the cost and inefficiency of management and to the difficulties of traders. In addition, the number of canal companies made it very difficult, even in a journey of considerable length, to get the advantage of the comparatively low tolls charged after the first 30 miles. It was absurd in a journey of 50 miles to be charged uniformly at the toll levied for the first 10 miles because the barge travelled over water owned by five different canal companies. There were, he thought, good grounds for hoping that practical good would result from the labours of the present Royal Commission on Canals, and that they would help to remove one of the greatest handicaps from which British industries at present suffered: the high cost of inland carriage.

Mr. W. Worby Beaumont (London) wrote that he agreed with Mr. de Salis' conclusion as to the use of steam-engines and internal-combustion engines for canal-boats, more particularly relating to the canals of Great Britain. He also agreed with his conclusion, at present at all events, that the steam-engine was in most cases the more suitable flexible motor, and that there was no doubt as to the force of objections of the kind he raised with regard to the use of petrol or petroleum in canal-boats. It was quite possible, however, that ere long suction gas-producers and gas-engines might be employed for propelling canal-boats.

Mr. J. A. Saner (Northwich, Cheshire) wrote that he had long been of opinion that drastic improvements, both as to management and capacity of many of the English canals, required undertaking. His views had been fully set forth in the paper written for The Institution of Mining Engineers in 1895;* also more recently in a paper read before The Institution of Civil Engineers in November, 1905,† for which the Telford gold medal was awarded; and also in his evidence before the Royal Commission on Canals and Waterways in May, 1906.‡ In these papers, he had uniformly advocated that main trunk-canals should be constructed for conveying cargoes of

* "Canals," by Mr. J. A. Saner, *Trans. Inst. M. E.*, 1895, vol. viii., page 467.

† "On Waterways in Great Britain," by Mr. John Arthur Saner, *Minutes of Proceedings of The Institution of Civil Engineers*, 1905, vol. clxiii., page 21 and plates i., ii. and iii.

‡ *Report of Royal Commission on Canals and Waterways*, 1906, vol. i., part ii., pages 35 to 51; and Appendix, third day, May 9th, 1906, pages 15 to 25.

not less than from 250 to 300 tons at a time. He knew that in the opinion of some others, as well as Mr. de Salis, a boat of 60 tons was considered to be sufficient; but there was really not very much difference between what they advocated and what he had been advocating, inasmuch as everyone was agreed that a train of boats should be able to carry far in excess of this amount, and that, therefore, the locks must be large enough to take several boats, in which case they would also be large enough, should occasion require and circumstances develop (and he felt certain that they would) to allow of the use of larger craft. He had not, of course, advocated the improvement of all canals, in the first instance, but had taken cross-country routes, such as Liverpool, Birmingham and London; Hull, Birmingham and Bristol; and Manchester and Hull, as being the important routes. If these were made with locks suitable for taking either a train of boats, each carrying 50 to 60 tons, or vessels capable of carrying from 250 to 300 tons at one locking, it would then be possible gradually to improve the smaller canals in such a manner that the smallest canal would eventually be able to take a boat of 60 tons. He quite agreed that a boat of 50 to 60 tons was the smallest which could safely navigate the estuaries of the Mersey and Humber, as he had had experience of such boats navigating both these estuaries. If canals were made so that these boats could penetrate to nearly all parts of the country, it would in his opinion effect a very great saving to the community in the cost of carriage; but he did consider that main canals should be large enough to accommodate craft of 250 to 300 tons, as he was quite convinced that within a short time after such canals were made, trade would so arrange itself as to enable them to carry full cargoes.

Some years ago, he made a tour of inspection through some of the foreign canals, especially those in Belgium and Germany, and although the circumstances of trade in this country were somewhat different from those obtaining there, it was quite certain that the main through routes as suggested above would, within a few years, fully compensate the promoters and constructors, whether such promotion and construction was carried out under Government guarantee or by private enterprise.

He would like to remind the members that, despite all difficulties and apparent losses entailed through the construction of the Manchester ship-canal, that canal had already improved the

trade of Manchester to a marvellous extent, and was now well on the way to remunerating those who had supported it by lending money.

Mr. F. S. GIRDLESTONE (Bristol Docks) wrote that there had recently been signs of considerable activity in connection with the canal-traffic between Bristol and the Midland counties; and the Sharpness New Docks and Gloucester and Birmingham Navigation Company, who owned the canal, and the Severn and Canal Carrying Company, who carried the traffic, were actively interesting themselves in the question of shipments from the Midland counties at Avonmouth dock. This had been brought about to a very large extent by the increased opportunities for shipping at Avonmouth and the progressive policy of the Bristol Docks Committee in assisting in the effort to make the facilities of Bristol better known in the Midland counties. In Birmingham, a commodious warehouse was being constructed to replace the small building which had hitherto existed, and electric cranes and other modern appliances were being erected on the wharf to expedite the loading and unloading of merchandise. Recently the Gloucestershire and Birmingham Navigation Company had been able to get the whole of the towing into their own hands, and improvements had been effected in this direction so that whereas formerly steam-tugs were only used to tow canal-boats through the tunnels between Worcester and Birmingham, they were now used throughout the whole journey (with the exception of a short distance between Tardebigg and Worcester, where there was a considerable flight of locks and steam-towing would be of no advantage). The Severn and Canal Carrying Company had been induced to quote rates sufficiently low to secure various classes of traffic for Bristol which had not hitherto been shipped at that port, and a very substantial margin could be shown between canal and railway rates from the Midland counties to Bristol, and an even greater saving as against the rates to Liverpool. There was also a margin in favour of Bristol, between Birmingham-Bristol and Birmingham-Liverpool canal rates respectively. The time occupied in the journey was, however, still an obstacle in the way of getting this route generally used, as it was not safe to calculate on less than five days for goods from Birmingham, and it required a longer period for goods from Wolverhampton and other districts.

The reorganization of authorities might then be accomplished by the establishment of single governing bodies for each of the great through routes, comprizing representatives of the various canal and navigation authorities now controlling the different waterways of which each was composed. Such bodies would be analogous in constitution to the Thames Conservancy Board and the Metropolitan Water Board, being representative of all the bodies entrusted with the regulation of the through route; and their creation would promote the process of amalgamation and the establishment of the clearing-house system, which had been the chief factors in the success of the railway companies. At present, whilst each through railway route was governed by a single company formed by such amalgamations—the London and North-western Railway Company, for instance, was a combination of forty or fifty small companies—there was not a single through water-route which was controlled by less than ten different authorities; there were twenty-six competing bodies on the three connecting London and Liverpool, and twenty-seven on the four between London and Bristol. Such combinations of waterway authorities might be authorized to purchase links in through routes owned by railway companies, which, it might be noted, were now prohibited from acquiring any canal-interests without express statutory provision; but, as such links were apparently often retained by such companies at a loss, it would obviously be to their interest to co-operate in a scheme which would relieve them of some of their surplus traffic. The advantages of a clearing-house system had been so often demonstrated since its establishment was rendered possible, 19 years ago, by Section 44 of the Railway and Canal Traffic Act, 1888—notably in a report of 1892 by Mr. Waghorn, counsel to the Cheshire Conference on Railway and Canal Rates—that it was needless to enter into them. It might, however, be pointed out that there were various provisions in the abovenamed Act, the systematic utilization of which by a strong combination of navigation authorities might materially tend towards the improvement of waterways and their freedom from railway-control. These were: the power conferred on the Railway and Canal Commissioners of making orders for the alteration of rates levied on railway-owned canals, where they could be proved to be calculated to divert traffic to the railway to the detriment of the

canal or persons sending traffic over it or other adjacent canals (section 38); the extension of the provisions of the Railway and Canal Traffic Act, 1854, and the Regulation of Railways Act, 1873, requiring railway companies to afford all reasonable facilities for forwarding traffic from railways to canals (section 37); the authorization of canal companies to enter into contracts and arrangements for through tolls (section 43); and the provision for the inspection by the Board of Trade of all canals dangerous to the public, or liable to cause obstruction to traffic, and the provision for their abandonment, if necessary, or, should the Board of Trade think fit, their transfer to any body of persons or local authority (sections 41 and 45). The last-named provision seemed especially noteworthy, with regard to the acquisition of all the links on any through route by a single governing authority.

Although Mr. de Salis expressed himself in favour of State control of the main routes of waterway, he did not say whether he also advocated their ownership by the State. As regarded the first point, the State already possessed a limited control of this kind, administered through the Board of Trade, which might be extended by statute for the purposes above suggested if necessary. In order that it should be thoroughly effective, such an extended control ought to be vested in a Special Water Department of the Board, entrusted not only with the regulation of navigation, but also with the conservancy of the water-system of the United Kingdom, on which not only navigation, but fisheries and water-supply for industrial and domestic purposes, were also dependent. The formation of such a department had been suggested by both the Salmon Fisheries Commission of 1902, and the Sewage Disposal Commission in their Report of 1903-1904, who also urged the appointment of subordinate boards for each watershed area, constituted on the lines of the river-boards or joint committees of county councils, which were now charged with the prevention of pollution in the rivers of the West Riding of Yorkshire, and the Mersey, Irwell and Ribble.

With respect to the State purchase of canals, it must be borne in mind that the Caledonian and Crinan canals in Scotland, and the Maigue, Boyne, Tyrone and Shannon navigations in Ireland were the property of the State, and that they could not be regarded as being better managed or more remunerative than

waterways belonging to canal companies or ordinary navigation authorities. Although theoretically attractive, State purchase of the inland navigations was also open to the weighty objections of the difficulty of obtaining the money necessary for the purpose; the opposition that it would naturally arouse amongst the most successful canal companies, such as the Aire and Calder, Weaver, and Leeds and Liverpool; and the length of time requisite for carrying out effectively any scheme requiring the consent of Parliament. Its feasibility might, however, be experimentally tested by the acquisition by the State of any one of the main through waterways, or by its construction of one of the new canals projected during recent years—such as that for a canal capable of accommodating steam-barges connecting the Thames and Mersey; that for the improvement of the Wilts and Berks canal; that for connecting Birmingham with the Trent and the North Sea; or the ship-canal for connecting the English and Bristol Channels favourably reported on by Mr. Thomas Telford and Capt. Nicholls, R.N., in 1825. In conection with such projects, it appeared worth noting that nearly all the main water-routes ran from north to south, and that the construction of one uniting the Wash with the Bristol Channel might restore to the East-coast ports some of the large trade that they enjoyed, until the construction of Denver sluice at the close of the seventeenth century caused the silting-up of the Wash rivers.

Mr. W. H. Hunter (Manchester) wrote that no one could deny that, for the greater part, the inland-navigation system of Great Britain was no better than an anachronism, which might have been tolerable (though even this was doubtful) 50 or 60 years ago, but which was intolerable now. The striking instances given by Mr. de Salis of the hopeless manner in which the routes between London and Leeds were blocked, were sufficient to prove this point to demonstration. The difficulty was not so much to find a remedy for the admitted evil as to impel the traders and others interested in the matter to seek the means for giving effect to remedial proposals. Whatever the Royal Commission on Canals and Waterways, which was now sitting, might, in their wisdom, recommend, it seemed futile to expect that, in the present state of public opinion in this country, funds for canal-improvement and development could be

obtained, either from the Government, or from local authorities. It was a self-evident proposition that an improved system of inland navigation would be of great benefit to the commercial interests of Great Britain, but it must be admitted that a great part of the benefit would be due to the manner in which facilities for the water-carriage of goods would bring about a reduction in the rates for rail-borne traffic, to the detriment of the shareholders in British railways. Under these circumstances, it could not be supposed that the great railway interest would remain supine when efforts were being made to introduce effective competition with railways by means of canals constructed or improved out of public money; or that the mass of the people of this country, who had no direct interest in inland navigation, would be willing to submit to an increase in the burden of rates and taxes, already so onerous, for the sake of inducing this competition, either from the point of view of pure patriotism, or with the hope of obtaining certain commodities at a slightly cheaper rate. On the other hand, no man of affairs would at this present time delude himself with the hope that the private investor who looked only for a direct and immediate return for his money, could be persuaded to provide the capital necessary for so great an undertaking as that which would be required if our inland-canal system were to be brought up to date. A direct return of a satisfactory character could only be looked for in special cases where special trades were concerned—because, except in respect of the transport of minerals and heavy raw materials, the trade of this country was so largely of a retail character, that was to say, was distributed in such small parcels, that a smaller unit of conveyance than any canal-boat could supply was required for the conveyance of traffic. There were one or two points of detail, which might be regarded as fitting subjects of criticism in Mr. de Salis' paper, but they were not of great importance. As an instance, he described upland rivers made navigable by the provision of locks and weirs as having, usually, a stream flowing downwards with a velocity up to 3 or 4 miles an hour. If he had divided these figures by 3, he would have been much more nearly correct: the figures which he suggested represent flood-velocities. Again, in dealing with the question of motors now available for the propulsion of canal-boats, Mr. de Salis referred in a somewhat deprecatory manner

to internal-combustion engines; but he made no reference to a class of motor from which it seemed at the present time more was to be hoped for than from any of those named by him, that was to say, oil-engines of the Diesel type, which used crude petroleum-oil as fuel, in which no explosion took place, and in which the oil was ignited by compression, without any of the magneto-electric or other sparking arrangements which caused trouble and difficulty in so many gas-engines.

Mr. G. W. Keeling (Cheltenham) wrote that his experience, and probably that of other engineers engaged on schemes for the improvement of waterways on which the income was insufficient to pay both the expenses and the interest on obligations, had been, that a large amount of sympathy, enthusiasm and moral support could be obtained in favour of schemes for the improvement of canals from traders, manufacturers, and public bodies. But the lack of financial support was probably due to the fact that business men, whilst appreciating the effect of navigable waterways on the carriage of heavy goods in convenience and rates, had no faith in such waterways being remunerative. This feeling had possibly given rise to the proposal that the waterways should be improved and maintained by the State or by the county councils. He (Mr. Keeling) did not advocate the general enlargement of canals and making them of uniform gauge.

In many cases, the sources of traffic and the supply of water would not justify the very costly works involved and the expense of securing a larger supply of water. Canal-boats had a very useful size (carrying 36 tons) and two of them abreast would pass through a barge-canal lock. He (Mr. Keeling) suggested that the convenient and economical course would be to leave the waterways in the hands of the present proprietors, but to encourage the formation of trusts for districts; and that the State or the county councils should have power to advance capital, where necessary, for improvements desirable in the public interest, or to guarantee the deficiency in interest on such capital—subject to the condition that the tolls charged, and the maintenance and management of the waterway, should be to the reasonable satisfaction of the officers representing the State or the county councils. With regard to railway-owned

canals, in many cases the railway companies were compelled to take them over, either by Act of Parliament or to satisfy the opponents of the railway bill, and in any case the transfer was sanctioned by Parliament. If it were now proposed to take such navigations out of the hands of the railway companies, with the object of their becoming active competitors for traffic, it appeared fair and reasonable that the capital expended by the railway companies in acquiring such canals or navigations should be returned to them; and, in cases where the railway companies had been required to guarantee interest on canal stocks, that they should be relieved from such guarantees. Of railway-owned canals, the Kennet-Avon canal-navigations and the Birmingham canal-navigation were also well maintained. The towing path on the river Severn, between Gloucester and Worcester, was not now of importance, as the Sharpness Dock Company undertook the towing, between Gloucester, Worcester and Stourport, with their steam-tugs, at moderate charges. The current, running at 12 knots per hour, referred to by Mr. de Salis, in the river Severn estuary, only occurred on the rising tide in high spring tides, at exceptional places, where the river was narrowed by promontories, such as at Beachley and at Old Sharpness point.

Mr. John Nevin (Mirfield) wrote that one difficulty often overlooked in inland navigation was the supply of water, especially in hilly country. Between Yorkshire and Lancashire, three canals crossed the Pennine chain. (1) The furthest south, the property of the London and North-Western Railway Company, was a narrow canal, from Huddersfield to Saddleworth: the locks being little more than 7 feet wide, would only take boats carrying a little over 20 tons; and very little traffic passed through it. This canal passed through Pule hill by a tunnel $3\frac{3}{4}$ miles long, and this canal-tunnel was stopped for more than a year, while the railway company were driving a new railway-tunnel. (2) The Rochdale canal passed through the hills between Todmorden and Littleborough, by locks, without a tunnel. By this route from Hull to Manchester, the boats passed through three navigations, in addition to the river Humber, between Hull and Goole: (*a*) the Aire and Calder navigation, from Goole to Wakefield; (*b*) the Calder and Hebble navigation, from Wakefield to Sowerby Bridge; and (*c*) the Rochdale canal,

from Sowerby Bridge to Manchester. The Aire and Calder navigation could take boats carrying over 100 tons; on the Calder and Hebble navigation, the smallest lock was 56 feet long and 14 feet wide, with a draught of water of 5 feet, and the boats could carry 60 tons. On the Rochdale canal, the locks were 68 feet long and 14 feet wide, with a draught of water of only 4 feet, and boats could carry 45 tons only. The Aire and Calder canal, fed from the rivers Aire and Calder, had a plentiful supply of water. The Calder and Hebble canal was fed from the river Calder, and the high level on the Halifax branch was supplied by pumping. The Rochdale canal had a limited supply from streams and reservoirs in the hills. (3) The third waterway from east to west, the Leeds and Liverpool canal, reaching from Leeds to Liverpool, crossed the Pennine chain between Colne and Skipton. It was supplied from streams and reservoirs, and the navigation was often stopped in summer for want of water. No further supply could be procured for these three canals, as the whole of the watershed was now taken up for domestic water-supply in Lancashire and the West Riding of Yorkshire. If the locks on the Calder and Hebble navigation were lengthened to the same dimensions as those on the Rochdale canal, and if the depth of the water in the Rochdale canal were increased at least by 1 foot, this through navigation would be much improved. It must be remembered, however, that if the dimensions or the depths of the locks were increased, more water would be used by each boat passing through them, and this would intensify the want of water now experienced in a dry summer. The expense of pumping was so great that it would be commercially impossible. The Rochdale canal and the Leeds and Liverpool canal at present only paid a dividend of 1 per cent. to their proprietors, and he could not suggest how any Act of Parliament was likely to reduce the expenses.

The PRESIDENT (Mr. Maurice Deacon) proposed a vote of thanks to Mr. de Salis for his paper.

Mr. G. E. COKE seconded the resolution, which was cordially approved.

Mr. DE SALIS, in acknowledging the vote of thanks, said that there was only one point upon which he would like to

reply, and that was the means of getting over a flight of locks by transport on wheels. The great difficulty was that the boats, if of any considerable size, must be taken out of the water and floated in a tank. The only craft that had been worked dry, uphill on wheels, had been small tub-boats of 4 or 5 tons, such as were formerly used on the Bude canal in Cornwall, and on the Coalport canal in Shropshire. A boat of any size, with a full load, could not be supported at two points. An accident occurred on the Grand Junction canal to a boat loaded with chalk, that came to a lock to go downhill. The man in charge drew the paddles to let out the water, and feeling thirsty adjourned to the adjoining public-house, leaving the boat to settle down of its own accord. A puff of wind blew the boat back and the stern settled on the edge of the sill, and before the water had fallen down more than 2 or 3 feet, the boat was broken in two.

The meeting then adjourned, and, on its resumption, Mr. James Cope Cadman took the chair.

Mr. W. B. M. Jackson's paper on "A Bye-product Coking-plant at Clay Cross" was read as follows:—

A BYE-PRODUCT COKING-PLANT AT CLAY CROSS.

By W. B. M. JACKSON.

Introduction.—In writing the following few notes on the working of a bye-product coking-plant with which the writer is connected, he does not claim to be able to find anything new to lay before the members, but hopes that the facts given will be of some interest, more especially to those members who are connected in any way with the manufacture of coke.

Coke has been manufactured at Clay Cross for many years, the date of the original ovens being 1840. These ovens, 9 feet long and 6 feet wide, of the bee-hive type, were erected under the supervision of the late Mr. George Stephenson, who at that time was one of the owners of the Clay Cross collieries, he having discovered the value of the coals existing in the neighbourhood, whilst making the tunnel at Clay Cross for the then North Midland railway. It is interesting to note that these ovens were erected for the purpose of producing coke to be consumed by locomotive engines; and, further, they were built with old stone sleepers that were taken up from the North Midland railway. These ovens numbered 52 in two double rows, and an old estimate shows that the cost of labour per oven was £3 7s. 4d. Large coal was used exclusively for coke-making, taken from the Low Main or Tupton seam. The coal made a large coke which was used in the blast-furnaces. From time to time, the coke-ovens have been altered, improved and added to, and another range of bee-hive ovens, 50 in number, was built in 1870. These ovens, 10 feet 4 inches in diameter and 8 feet high to the apex, were built with flues, and the waste-gases were used for generating steam at two egg-ended boilers at a colliery close by. In 1889, 37 ovens of the original battery were rebuilt: these ovens were 10 feet 6 inches in diameter and 8 feet 2 inches high to the eye; and the waste-gases generated steam from three egg-ended boilers. Washed and crushed coal from the Black-shale and Tupton seams was used in these ovens.

Experimental Coke-ovens.—Some years later, it became apparent to the writer that retort-ovens and a bye-product plant for dealing with the waste-gases must lead to more satisfactory results. Considerable doubt existed as to whether the slack from the Clay Cross collieries would be suitable for the manufacture of coke in retort-ovens; and, after many installations both in this country and on the Continent had been inspected, it was decided that it would be advisable to erect a small number of trial-ovens. Eight ovens were therefore built in 1904 by the Simplex Coke-oven and Engineering Company, Limited, the agents for the Entreprises de Constructions de Fours à Coke et d'Usines Métallurgiques. These ovens, 33 feet long and 6 feet 9 inches high, were arranged in pairs, each pair being of a different width, the first being 24 inches; the second, 26 inches; the third, 28 inches; and the fourth, 30 inches; with a view to ascertaining the most suitable dimensions. It was proved that the narrowest ovens gave the most satisfactory results, and, ultimately, when the main battery was built, the width of the oven was again reduced, as will be shown later. The side-flues of the ovens were horizontal, and were three in number. The eight ovens were divided into two sets of four, varying in the manner in which the gas passed in the flues; one set was arranged so that the gas entered at one end and passed the full length of the ovens and thence to the waste-gas flue. In the other set, a dividing wall was built midway in the flue, and the gas was admitted at both ends and coursed backwards and forwards between the end and the dividing wall, as shown in fig. 1 (plate xii.), and so underneath the oven itself into the waste-gas flue. It was found from experiments that the latter form of flue gave the best results: the heat being more regular and easier to control.

At first, the slack, after being washed and crushed, was put into the ovens from the top; but the results were not entirely satisfactory, the coke coming out small and not of a very good appearance. Experiments, therefore, of a somewhat rough character (owing to the absence of anything in the nature of machinery), were made to prove, as far as possible, what would be the result of compressing the slack. This was done by filling wooden boxes with slack, and compressing by hand: the bottom of the box was then drawn into the ovens, with the compressed

cake, and during the process of carbonization the wood was burnt and the slack was left as a cake of coke. The advantage of compressing was immediately observable and the small quantity of coke, made from slack compressed in boxes, was larger and better in every way than the remainder of the charge.

Simplex Retort-ovens.—After this plant had been at work long enough to prove that a really good coke could be made from the slack in bye-product ovens, by means of using a compressor, a contract was entered into with the Simplex Coke-oven and Engineering Company, Limited, for the erection of 34 ovens and a complete bye-product plant: it being arranged, should it be deemed advisable to extend the plant by an additional 16 ovens, that the bye-product plant should be capable of dealing with this extension. These ovens were completed and set to work in November, 1905, and consisted of 34 bye-product recovery-ovens and a bye-product plant, with three Lancashire boilers, 30 feet long and 8 feet in diameter, heated by the waste-gases, and working at a pressure of 100 pounds per square inch. The plant was enlarged in January, 1907, by the addition of 16 ovens and two Lancashire boilers, 30 feet long and 8 feet in diameter.

The complete plant consists of 50 Simplex bye-product recovery-ovens, with a bye-product plant for the recovery of sulphate of ammonia and tar; five Lancashire boilers, 30 feet long and 8 feet in diameter, heated by the waste-gases, and working at a pressure of 100 pounds per square inch; and a chimney. The crushing plant comprizes a Carr-type disintegrator, 4 feet 6 inches in diameter, driven by a Tangye engine, with a cylinder 13 inches in diameter and 26 inches stroke, developing 42½ horsepower, under full load, when running at 90 revolutions per minute. About 25 tons of slack are crushed per hour, but this quantity can be increased if necessary. Electric power is supplied by a steam-turbine, running at 3,000 revolutions per minute, coupled direct to a continuous-current, compound-wound dynamo producing 50 kilowatts at 110 volts. The current is taken to the 38 horsepower motor, actuating the travelling gear and ram in the travelling charging-machine; to the 8 horsepower motor, working the stampers; and to the 15 horsepower motor, elevating the slack into a storage-tower of 450 tons capacity. The arc and incandescent electric lamps, lighting the

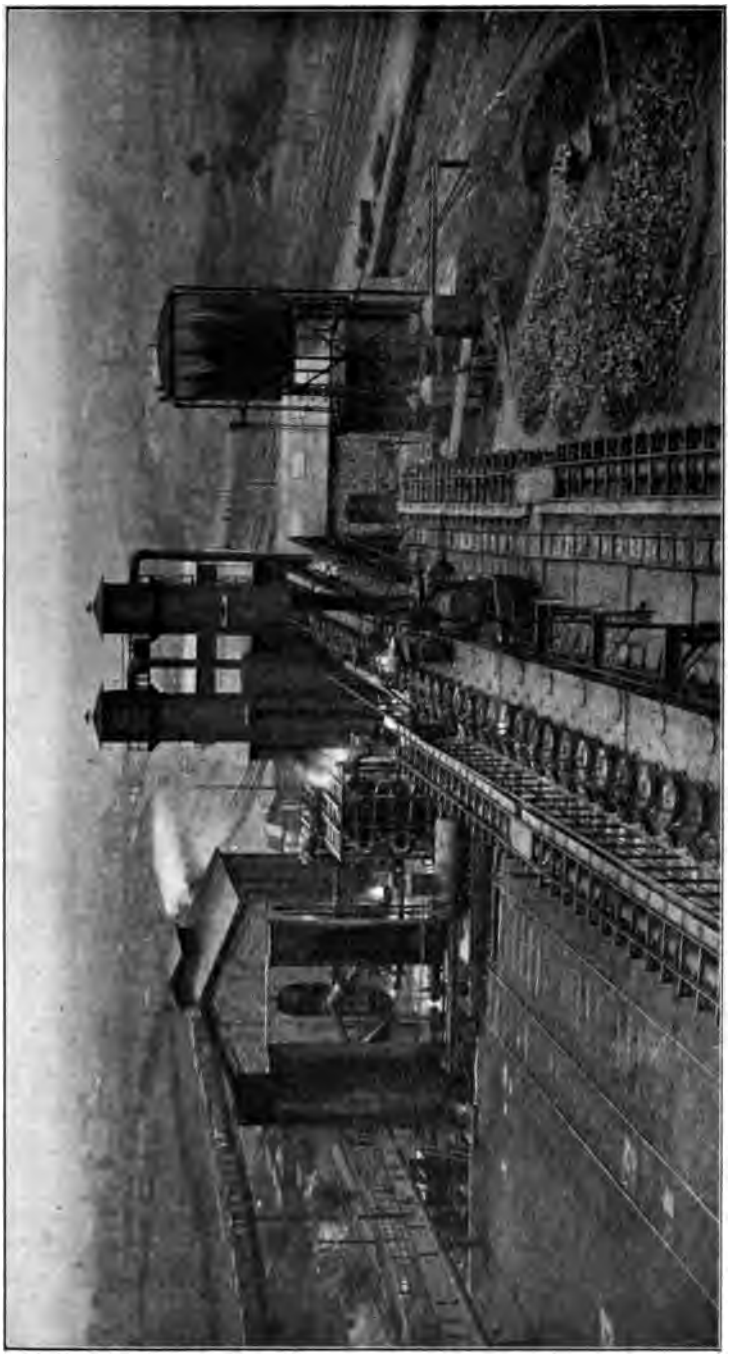

FIG. 4.—SIMPLEX COKE-OVENS AND BYE-PRODUCT PLANT.

works, are supplied from the same source. The plant occupies a total area of about 2 acres of land, situated inside the works of the company, and within 600 feet of the blast-furnaces. Figs. 1, 2 and 3 show the general arrangement of the plant. The ovens are constructed on the Fabry-Linard principle: each oven being 32 feet 9 inches long, and 20½ inches wide at the charging end, tapering to 22 inches at the discharging end. The height at the springing of the arch is 6 feet, and at the crown of the arch 6 feet 7 inches.

The slack for coke-making, taken from the Black-shale and Tupton mines, is sent from the various pits belonging to the company to a central station where it is washed in a Barraclough washery. This machine is of the pulsating type, the dashers or pistons being attached to a horizontal shaft, working through a stuffing-box on the side of the washer-tank. The pistons, 20 inches in diameter and 6 inches stroke, make 68 strokes per minute. From 10 to 12 per cent. of dirt is washed out. The washed slack, delivered in railway-wagons at the crushing-plant, is emptied into a hopper and raised by an elevator to the disintegrator, where it is crushed and drops down into a hopper to be raised again by an elevator into a storage-chamber.

The bottom of the storage-chamber is arranged with sliding doors, through which the slack is drawn into charging wagons on rails at the level of the top of the ovens. The pear-shaped wagons, holding about 32 cwts. of slack, are emptied into a hopper, carried on the charging machine. The contents are then emptied into the charging and compressing box, which has a capacity of 8½ tons: the charge of each oven. The charging and compressing box is made of the same length, width and height as a coke-oven. The slack is compressed in layers by means of electrically-driven stampers. There are two stampers, each weighing 400 pounds, travelling backwards and forwards by an automatic arrangement over the whole length of the charge.

As soon as the slack is compressed to a sufficient solidity, the machine travels behind the coke-ovens to the oven about to be drawn; the oven-doors are then lifted by hand-winches (fig. 1, plate xii.), and the ram is set in motion. This ram pushes out the coke, and, on being drawn back, the machine is moved about 3 feet so as to bring the charging apparatus into line with the

FIG. 5.—NORTH SIDE OF SIMPLEX COKE-OVENS, STORAGE-CHAMBER AND CHARGING-MACHINE.

oven. The compressed slack is then pushed forward into the oven on a forged-steel plate, forming the bottom of the compressing box; the doors at each of the ovens are closed, and the plate is drawn back, leaving the slack in the oven. The travelling compressor is then moved back to the charging-place, where it is again filled ready for the next oven. The whole of the machinery is actuated by continuous-current motors; and since the ovens have been started, now 18 months, there has scarcely been a hitch in the working of this machine. The time occupied in filling, compressing, removing to the required position, drawing the coke, re-charging the oven, and returning to the point at which the slack for a further charge is taken into the machine, is on an average something less than 35 minutes. The time occupied in coking averages 36 hours.

Considerable difficulties were experienced at first in the quenching of the coke. This has now been overcome, and the quenching is effected by water at a pressure of 40 pounds to the square inch. In the opinion of the writer, the higher the pressure at which the quenching water can be discharged the better. The coke is pushed out of the oven on to a platform 45 feet in length, with an inclination of $1\frac{1}{2}$ inches to the yard. The hose-pipe is played on to the coke from both sides during its discharge from the oven; and the coke then stands upright in a mass. A 2 inches wrought-iron pipe is then connected to the hose-pipe, this pipe being bent in the form of an inverted U with the opening pointing downwards; and it is moved along the whole length of the coke. After this watering, the mass of coke divides in the centre longitudinally, and is pulled over by the men; and the rest of the required quenching is carried out by hand. When cooled, the coke is loaded by forks into steel barrows, and from these it is filled into wagons, the tops of which are level with the bench.

The gas generated in the process of coking the slack is drawn through a pipe, E, 12 inches in diameter, fixed midway on the oven (fig. 1, plate xii.). This pipe then delivers into a dry gas-main connected with the exhausters of the bye-product plant through the various coolers. The return-gas, used to heat the ovens on its way back from the bye-product plant, is divided into two mains,

A and A_1, carried the full length of the battery, one on the front of the oven and the other at the back. Connections are made from these mains to each heating-flue by means of pipes, a, and a_1, 1½ inches in diameter, with nozzles entering the flues: nozzles, b and b_1, are the main gas-inlets, and c and c_1 are additional inlets. The gas from the upper or main nozzles, b and b_1, passes along the flues, f and f_1, until it is deflected downwards by a cross-wall, i, in the flue into the second flues, g and g_1. At this point, additional gas-inlets, d and d_1, are provided; the gas travels outwards and meets a fresh supply through the nozzles, c and c_1, and is again deflected downwards into the third and lowest side-flues, h and h_1. It travels inwards again through the flues, h and h_1, and then into the flues, k and k_1, underneath the oven. The gas from the charging end of the ovens passes from the centre of the sole-flue, l_1, outwards through a damper, m, and into the main collector-flue, C, extending the whole length of the ovens. The gas from the opposite end passes outwards from the centre of the sole-flue to the coke-bench end of the oven and then through a portway, o, into the sole-flue, l, under the next oven. It traverses the whole length of this flue, and passes through a damper, m, into the collector-flue, C. It will be seen from this description that the gas, after entering the bottom flue, is divided by the cross-wall, i, one portion passing straight into the collector-flue, a distance of half the length of an oven, while the other portion, before it reaches the collector-flue, has to traverse the length of one-and-a-half ovens. Each bottom-flue being fitted with a damper, the amount of gas passing can be regulated so that both flues are kept at the same temperature; and it has been found that any variation in wind-pressure can be neutralized by this arrangement.

Air is admitted at two points, (1) round the main gas-nozzle, b and b_1, and also through a grid, e and e_1, at each end of the oven, the air passing down three openings to meet the gas in the top side-flue, f and f_1.

The expansion of the ovens after lighting was about 1 in 144.

The quantity of coke produced per week by the 50 ovens is 1,100 tons, each oven producing about 22 tons. The yield of coke is 67¾ per cent., calculated from the dry slack after being washed. The slack contains 32¼ per cent. of volatile matter, and

the average quantity of moisture in the slack, when put into the ovens, varies from 12 to 15 per cent. Analyses are made two or three times a day from samples of the slack, taken as delivered into the ovens. It may be considered that 15 per cent. of moisture is somewhat high, but the quantity has been determined after experiment; and it is found that the largest and best coke physically is produced from slack containing from 12 to 15 per cent. of water. An average analysis of the coke is as follows:—Fixed carbon, 85·30 per cent.; ash, 10·20 per cent.; volatile matter, 1·00 per cent.; sulphur, 1·50 per cent.; and

FIG. 6.—NORTH SIDE OF BYE-PRODUCT PLANT.

moisture, 2·00 per cent. The coke is used in the Clay Cross blast-furnaces, and the balance is sold for blast-furnace purposes. It is a very good coke. The proportion of breeze is 1 per cent.

No trouble has ever been experienced in the working of the ovens since the commencement, except on one occasion, shortly after they were originally started, when the heat was lost for a few hours. This occurred when the ovens were first connected with the bye-product plant, as for the first week the ovens were worked without the bye-product plant; but since that time there

has not been a hitch of any sort. Nothing has been spent in repairs to the ovens, and they show at present no sign whatever of any deterioration.

The number of men employed in connection with the coke-burning is 20 on each shift, and it is, of course, scarcely necessary to say that the ovens are working continuously throughout the year.

Bye-product Plant.—The bye-product plant is erected at the eastern end of the ovens, there being an open space of 30 feet between the ovens and this plant. The plant is arranged in the

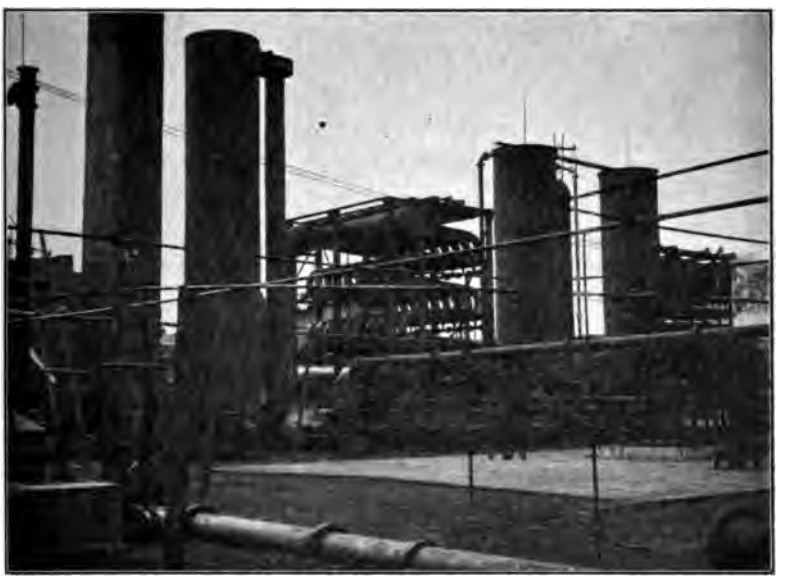

FIG. 7.—EAST SIDE OF BYE-PRODUCT PLANT.

form of a hollow square, the various coolers, scrubbers, etc., on the four sides and the large underground tank for the tar and ammoniacal liquor in the centre.

The temperature of the gas leaving the ovens is 482° Fahr. (250° Cent.). From the dry gas-main an inclined pipe conveys the gases to the bottom of the first air-cooler. This pipe is extended and left open, the open end being closed by dipping into a small water-tank; the gases pass in succession through two air-coolers; a serpentine cooler, which can be used either as an air or as a water-cooler; three water-coolers; a tank in which the

remainder of the tar is caught; and thence to the gas-exhauster in the enginehouse. There are two exhausters, one of which is used and the other forms a duplicate, driven by horizontal steam-engines. Steam is conveyed to these engines and for other purposes to the bye-product plant in pipes from the boilers, which are situated at the other end of the coke-ovens. These engines drive, by a countershaft, various belt-driven water, tar and ammoniacal-liquor pumps. The exhausters maintain a partial vacuum of 5 inches of water. After leaving the exhauster, the gases pass through a Pelouze-Audouin separator, which extracts any remaining trace of tar; and then through a serpentine water-cooler to two scrubbers, where the gases entering at the bottom meet, in rising, a stream of falling water which is broken into spray by a number of wooden hurdles placed 1½ inches apart across the scrubber; thence the gases pass through a gasometer; a water-seal tank to prevent an explosion at the ovens from reaching the bye-product plant; and so back to the ovens.

The ammoniacal liquor from the scrubbers, being carried into the large tank in the centre of the plant, is pumped into stills, where the free ammonia is liberated from the liquor by coming into contact with steam, and the fixed ammonia is liberated by treatment with lime. The ammonia gas is then conducted by pipes into a sulphuric-acid bath, where it is converted into sulphate of ammonia. And after the sulphate has passed through a centrifugal dryer, it is stored ready for sale. The average weight of sulphate of ammonia produced per ton of slack coked is 32 pounds.

The tar, collected into the central tank, is pumped into an elevated tank, from which it is run into railway tank-wagons. The weight of tar produced is 67¼ pounds per ton of coal carbonized. The tar is sold in the crude state to refiners, as it was not considered worth the expense of erecting a plant to deal further with that bye-product.

The cooling water necessary for the recovery of bye-products from the 50 ovens is approximately 4,500 gallons per hour, at a temperature not exceeding 63° Fahr.

After the waste-gases have passed from the ovens, as previously described, they are conveyed to the boilers. These are evaporating 500 gallons of water per boiler per hour, the pressure of the steam being 100 pounds per square inch. The steam is utilized

for the coal-crushing plant, for the steam-turbine, and in the bye-product works. The surplus steam is used to drive the fitting-shop and foundry engines, at a distance of some 600 feet from the boilers.

The company supply a considerable area round their works with gas, making on an average some 50,000,000 cubic feet a year. It was found that the waste-gases from the ovens were in excess of that required for the generation of steam, and a main was laid from the ovens to the gas-works, a distance of about ½ mile. A meter was fixed at the end of the main, near the coke-ovens, and the gas is conveyed from the coke-ovens to the gas-works, entering the purifiers and mixing there with ordinary coal-gas manufactured at the gas-works. It has been found that this gas is a good illuminant, with a candle-power, when used by itself, of 14½; when mixed, however, with ordinary coal-gas, the candle-power is raised to 17 before distribution to the public. This has been found to be perfectly satisfactory, and has proved an economy both in coal-consumption and in labour.

The CHAIRMAN (Mr. J. C. Cadman) moved a vote of thanks to Mr. W. B. M. Jackson for his interesting paper.

Mr. ISAAC HODGES seconded the resolution, which was cordially approved.

Mr. A. VICTOR KOCH's "Notes on Bye-product Coke-ovens, with Special Reference to the Koppers Oven" was read as follows:—

NOTES ON BYE-PRODUCT COKE-OVENS, WITH SPECIAL REFERENCE TO THE KOPPERS OVEN.

By A. VICTOR KOCHS.

Introduction.—The main object of this paper is to explain the design and construction of the bye-product coke-oven invented by Mr. Heinrich Koppers, of Essen, Germany, and to point out the special features which distinguish it from other systems. But, as coke-ovens of the kind have not been employed in this country to any considerable extent, the construction and the working thereof are comparatively little known to colliery and iron-works engineers, and it has therefore been thought that a few preliminary remarks on the general design and advantage of this type of oven would not be out of place.

The introduction of the original non-bye-product retort-oven had for its object the acceleration of the carbonizing process by employing the gases of distillation for heating the oven-walls; which was not previously the practice with beehive ovens. The long rectangular form of the oven was, of course, chosen to enable the coke to be mechanically discharged from the oven. The step from the ordinary retort-oven to the bye-product oven was a simple and natural one, and it is a matter of great surprise that up to the present so few plants have been erected in this country. All coke-oven builders are practically of the same opinion as to the general shape of the ovens; and it is principally in regard to the method of heating the ovens and the arrangement of the heating-flues, which are, of course, the most important points to be taken into account, that the various ovens differ one from the other.

The main points of difference between the several systems of ovens may be summarized as follows:—(1) The arrangement of the heating-flues; (2) the facilities for inspecting the heating-flues; (3) the method of applying and regulating the heating-gases; and (4) pre-heating the air for combustion.

Heating-flues.—The ideal requirements of bye-product coke-ovens are quite obvious, and may be concisely stated to be the uniform heating of the oven-walls along the whole length of the ovens, combined with easy and perfect means for inspecting the working of the ovens and for regulating the combustion. In order to attain these requirements, many designs have been brought out, showing various arrangements of heating-flues, but there now seem to be only two flue-arrangements which have survived, namely, the vertical and the horizontal. Of these two designs, it can safely be stated that the vertical flue has been by far the most popular, as the great bulk of the ovens which have hitherto been built are of this construction. It might be mentioned that the employment of horizontal-flued ovens has in Germany been practically abandoned.

It is claimed for horizontal flues that they permit of the working of the ovens being better supervised and controlled, owing to the facilities provided for inspecting the heating-flues whilst the ovens are at work. This is certainly an advantage over ovens in which the heating-flues cannot be examined. The great function of the flues, namely, to heat the oven-walls uniformly, is, however, in the writer's opinion, sacrificed to attain this object, as it is evident that to heat uniformly a chamber 33 feet long, it is absolutely essential that the side-walls be heated at the greatest possible number of points with jets of equal intensity. The construction of horizontal-flued ovens will not permit of more than three or four jets being employed at each end of the oven; and it is quite evident that the walls cannot be so equally heated as the walls of vertical-flued ovens having a large number of heating jets distributed along the whole length of the oven. This will be clear when it is borne in mind that the greatest heat of a flame is a little beyond the point of combustion, and it is, therefore, obvious that the walls of horizontal-flued ovens are overheated at the few points of ignition of the gas and air, whilst the other portions of the wall are comparatively cool. In horizontal-flued ovens, furthermore, the top flue is heated to a high degree, and it is generally admitted that this is a disadvantageous feature, as the great heat has the effect of decomposing the gases of distillation and entailing a consequent loss of bye-products. With vertical-flued ovens, on the other hand, the greatest heat is generated at the lowest point of the

oven; and the top portion of the oven is much cooler, there being a difference of from 200° to 300° Cent. (392° to 572° Fahr.) between the temperatures at the top and bottom of the oven.

Some ovens of the horizontal-flue type are arranged with a dividing-wall between each oven; and it is commonly supposed that the provision of this wall is an advantage, in that it acts as a store for heat and prevents the temperature of an oven from being affected when the next oven is freshly charged with coal. This theory, in the writer's opinion, has no foundation in fact; but, on the contrary, the central wall is a distinctly disadvantageous feature, because it necessitates the provision of double the number of flues, which has the effect of extending the length of a battery of ovens by from 50 to 100 per cent. and thus increasing the area of heat-radiation to that extent. The heat lost by radiation in a battery of ovens with single-flued walls is calculated to be about 25 per cent. of the total heat supplied to the ovens; and as the radiation of heat is directly proportional to the surface exposed, it necessarily follows that heat will be lost in the same ratio as the battery is extended. Any advantage that the wall may have as a store for heat would therefore obviously be lost. It is true that the wall serves to prevent the temperature of an oven from being affected when the next oven is freshly charged. This, however, is no advantage over ovens having single-flued walls, as experiments have indisputably established the fact that no appreciable difference in temperature takes place in a single-flued oven when its neighbour is freshly charged. Even if such a difference of temperature took place, no loss in heat would occur, as any heat extracted would assist the carbonization of the coal in the cold oven. It might be added that the provision of a central wall cannot very well be dispensed with in ovens having horizontal flues, if air heated in the basement of the ovens is to be employed for combustion-purposes; as it is only by means of flues in the central wall that the hot air can be conducted to the points of combustion. The provision of a central wall is, furthermore, essential with ovens having horizontal flues, in order to afford sufficient support for the superstructure: it being quite evident that a wall formed of single-horizontal flues could not be regarded as being otherwise than a very weak construction. Walls of vertical-flued ovens, on the other hand, consisting, as they do, of a series of hollow columns of brickwork, are of very strong

construction; and there is, therefore, absolutely no necessity for providing a central wall with a view to increasing the strength.

Regulation of Working.—The next most important point which should be taken into consideration is the method of regulating the working of the ovens. The main object aimed at in the construction of coke-ovens is the production of a homogeneous coke; and, as this is only possible when every part of the charge is subjected to the same temperature, it is essentially necessary, not only that the oven should be heated at the greatest number of points along the whole length of the walls, but that each jet should be capable of easy regulation. In a number of ovens, the regulation has to be effected wholly from the galleries beneath the ovens, where the heat renders the work very uncomfortable; in consequence of which the regulation is neglected and, therefore, not properly performed. It happens in all ovens, from time to time, that dark places appear in the walls, indicating either that the flues are choked up or that the gas or air-admission requires adjustment. Such defects in the heating should be rectified immediately, and if the adjustment cannot be effected without trouble and discomfort, the workmen will not seek to remedy the defects. It is, therefore, quite evident how absolutely necessary it is that all means of regulation and adjustment should be easily accessible, in order that the heating can be controlled without any difficulty or discomfort.

Pre-heating of Air.—A point of great importance is the pre-heating of the air for combustion. The higher the temperature to which the air is raised, the less is the quantity of gas required for generating the necessary heat for carbonizing the coal. By raising the temperature of the air to the highest attainable degree (1,000° to 1,100° Cent., or 1,832 to 2,012° Fahr.) by means of regenerators, only from 45 to 55 per cent. of the total quantity of gas evolved from the coal is required for heating the ovens, the remaining quantity being available as a surplus for external purposes. In nearly all systems of ovens, the air is heated by conducting it through the galleries under the ovens and through air-channels formed in the brickwork-foundations of the ovens; but the heat thus gained is of no great value in enabling surplus gas to be produced in any quantity. In fact, in a number of

cases it has been found impossible to carbonise coal in ovens where the air is heated only by such means; and ovens arranged with regenerators have had to be adopted, as the entire surplus heat in the coal is produced in such ovens in the form of a combustible gas, the whole of which is available if necessary for heating the ovens. Ovens working without regenerators, on the other hand, produce the surplus heat in the coal mainly in the form of a hot waste-gas, which can only be used for boiler-firing and could not be made use of in any way for assisting the carbonizing process.

Development of the Koppers Oven.—The Koppers oven is arranged with vertical flues, and is a development of the old Otto-Hoffmann oven, which, for about 20 years, was the most popular oven on the Continent. The Otto-Hoffmann oven was, however, essentially a regenerator-oven, whilst the Koppers oven can be arranged to work with or without regenerators. The main feature of the original Koppers oven, in which it differed from the Otto-Hoffmann, was the separate distribution of gas and air, and causing combustion to take place in each separate flue along the whole length of the oven. This improvement had the effect of compelling the gases of combustion to pass up each flue instead of making their way up any flue according to the line of least resistance, as was the case with the old Otto-Hoffmann oven. The distribution of the heating thus effected was found to be a great improvement; but it was also found necessary, in order to be able to arrive at perfect uniformity in the heating of the walls, for each of the gas-inlets to be accessible for regulation. Openings were therefore subsequently made in the top of the ovens, one over each flue, by means of which the gas-admission nozzles could be taken out and replaced with the least possible trouble. The next step in the development of the oven was the provision of regulating sliding-bricks over each flue, which are accessible for adjustment through the openings at the top of the ovens previously referred to. Through the agency of these sliding-bricks the quantity of air entering each flue can be regulated to a nicety, and, in practice, it has been found to be a most important advantage.

Bye-product ovens which produce the surplus heat in the coal, that is the heat over and above that required for carbonizing the

coal, mainly in the form of a hot waste-gas, are not distinguished in this country by any particular name from those which produce the surplus heat wholly in the form of a combustible gas. In Germany, the name given to the former type of oven is *Abhitze Ofen* (waste-heat oven), whilst the latter is known by the name *Regenerativ Ofen* (regenerator-oven). As there is a distinct difference between the two systems, and the Koppers oven is designed on both principles, they are distinguished by the designations of waste-heat oven and of regenerator-oven.

Koppers Waste-heat Oven.—Plate xiii. shows longitudinal and cross-sections through the oven-chamber and heating-flues. Fig. 1 is a longitudinal section through one of the walls and shows the arrangement of the heating-flues; fig. 2 is a longitudinal section through the oven-chamber; and fig. 3 shows three different cross-sections through a number of ovens. The oven is a chamber 32 feet 10 inches (10 metres) long, 6 feet 7 inches (2 metres) high and from 20 to 24 inches wide in the centre. The height and the width, however, vary somewhat according to the class of coal to be coked. The top of the oven is provided with three openings, A, for charging the coal, and a fourth opening, B, through which the gases of distillation are drawn off to the condensing plant. The purified gas is returned from the bye-product plant by the main, C, placed in a position convenient for access, either in front of or at the back of the battery of ovens. Separate branch supply-pipes, D, fitted each with a regulating-cock, conduct the gas to each oven; and these branch pipes communicate with the gas-distributing channel, E, placed immediately below the heating-flues. This channel, E, is formed of fire-brick pipes, and runs along at the base of the whole of the heating-flues, with the exception of one or two at the end remote from that at which the gas is admitted, and these latter flues conduct the waste-heat to the main flue, P, leading to the steam-boilers. The heating gas passes out of the distributing channel through orifices each fitted with a gas-nozzle communicating with each vertical flue. The air for combustion flows along the conduit, F, and induced by the chimney-draught it is drawn into the air-distributing channels, G, situated immediately beneath the oven-chambers. The air enters each heating-flue through the openings, H, and meets the gas issuing through the gas-nozzles, U. Com-

bustion takes place a little above the nozzle, and it is to be particularly noticed that the comparatively cold air flows around the base of the nozzle (fig. 5, plate xiii.), keeps it cool, and prevents any likelihood of the nozzle setting fast. The products of combustion of the gas and air pass up the heating-flues, K, and through the openings, L, at the top of each flue. These openings are each furnished with a damper, M, which can be easily regulated so as to enable the exact amount of air to enter the flue necessary to effect perfect combustion. The sliding-bricks are accessible from the top of the ovens through the openings, N, which are fitted with easily removable plugs (fig. 4, plate xiii.).

At this point, particular attention should be directed to the sliding-bricks and to the openings at the top of the ovens which give access to them, as these are two of the principal features of Koppers ovens and distinguish them from all other constructions. The openings at the top of the ovens serve not only to provide means for regulating the dampers, but serve more particularly to give access to the gas-nozzles, U, and they further permit of the flues being inspected at any time. Without the facility thus provided for examining the flues, it would not be possible to work the ovens satisfactorily. The gas-nozzles are furnished with oval orifices, to enable them to be taken out by a rod having a tee end as shown in fig. 6 (plate xiii.). The orifices in the nozzles vary in size, according to their position in the flues. The removal and replacing of a nozzle can be effected in a few moments, without the slightest trouble or discomfort.

As already mentioned, it happens from time to time in all ovens that dark places appear in the oven-walls indicating that the combustion is defective; and, in the absence of means of access to the flues, it would be necessary to cool down the oven and break into the walls in order to remedy the defect. By means of the openings over each flue in the Koppers oven, the cause of any irregularity in the heating can be immediately detected, and in the great majority of cases such defect could be rectified in a few moments. The effect of any adjustment in the regulation of the gas and air can, moreover, be seen immediately; whereas in other ovens the effect of any alteration in the gas or air-supply can only be ascertained after the lapse of some time, and then only by the appearance of the wall inside the oven after the coke has been discharged.

FIG. 18.—KOPPERS COKE-OVENS AND CHARGING-MACHINE, MANVERS MAIN COLLIERY.

Other oven-builders, in endeavouring to provide similar facilities for regulating the combustion in the flues, have adopted means of adjustment at the base of the flues, to which access is obtained from the basement of the ovens. It has already been pointed out that the heat in the galleries beneath the ovens is too great to permit of the work of regulation being carried out without great discomfort. Apart from this the throttling of the air-inlets at the base of the flue has the effect of increasing the velocity of the air, so that the speed of the gases of combustion up the heating-flues would be unequal along the length of the oven, and the heating cannot, therefore, be uniform.

FIG. 19.—KOPPERS COKE-OVENS, BARNSLEY MAIN COLLIERY.

After passing through the openings at the top of the heating-flues, the gases of combustion flow along the horizontal flue, O, in the direction indicated by the arrows (fig. 1, plate xiii.), and finally pass down into the main flue, P, leading to the boilers. The outlet-flue from each oven is furnished with a regulating-damper, R, by means of which the chimney-draught is adjusted.

It will have been seen that each oven-wall is formed of about thirty vertical flues, and that each of these flues is provided with a heating jet and also with means for regulating the admission of the gas and air, namely, by substituting the gas-nozzles, and by

adjusting the sliding-bricks over each flue respectively. It is, therefore, obvious that it is easily possible to control the heating so that the oven-walls will be subjected to exactly the same temperature from end to end. This uniformity in the heating has been striven after by coke-oven builders for many years, as it is the ideal requirement; and, unless it be attained, it is impossible to produce a coke which will be homogeneous in character throughout the charge.

Experience has shown that it is a great disadvantage for the upper part of the oven-walls to be heated to an intense degree (as is the case with horizontal-flued ovens), as the gases of distillation become decomposed by the heat, which results in a loss of bye-products. In the Koppers oven, the zone of greatest heat is opposite the bottom of the charge of coal, and by the time that the gases of combustion reach the upper part of the oven the temperature is so much reduced that they will have no detrimental effect on the gases of distillation.

Besides the production of a homogeneous coke, the uniform heating of the ovens possesses another most important advantage, namely, that it enables the period of coking to be reduced, which results in an increased yield of coke. This will be evident when it is considered that, in ovens where the walls are more intensely heated at some points than at others, parts of the charge become carbonized sooner than the portion in the cooler part of the ovens, but the charge has to remain in the ovens until the whole is carbonized. It follows therefore that, with perfectly equally-heated walls, the carbonization of the whole charge is completed at the same time.

Koppers Regenerator-oven.—The Koppers regenerator-oven is designed on identical lines to the waste-heat oven, and differs only in that the air for combustion is heated to an intense degree by means of regenerator-chambers. The advantages of equal heating, easy means of regulating, and the facilities for inspecting the flues, which distinguish the waste-heat oven over other systems, are the same in the regenerator-oven.

The form of regenerators which was originally employed with the Koppers oven consisted of two long chambers filled with a chequer-work of fire-bricks, running the whole length of the battery of ovens in the position shown in figs. 7, 8 and 9 (plate

xiv.). The air for combustion enters at the end of one regenerator, and passes to each oven through the openings, W. After ignition with the gas in the heating-process of the oven, the resulting products of combustion pass through the heating-flues to the other regenerator, and, induced by the chimney-draught, they pass along to the chimney, giving up their heat to the chequer-work of fire-bricks. After a period of time, usually about 30 minutes, the air which entered the first regenerator has abstracted the heat from the chequer-brickwork; whilst the bricks in the other regenerator have been raised to an intense heat by the waste-gases going to the chimney. The direction of combustion is then reversed by automatic means, the air being admitted into the highly heated regenerator; and the products of combustion pass through the other regenerator, which again becomes heated to an intense degree. The air is heated to a temperature of about 1,100° Cent. (2,012° Fahr.), whilst the heat of the waste-gases is absorbed by the fire-brick chequer-work, to such a degree that the gases are quite black on entering the chimney and are useless for any further purpose.

In order to avoid the trouble and inconvenience which may be experienced through repairs having to be carried out in connection with the regenerators (which would always necessitate the whole battery of ovens being shut down), an oven was designed and patented by Mr. Koppers in which separate regenerator-chambers are provided for each oven. A large number of ovens of this construction have been erected, and have proved a great success. The new construction has a number of important advantages over the older form, apart from rendering the ovens independent of each other: the principal one is, that it permits of a better regulation of the air and of the draught for each oven. This point will be explained more fully later on. Another advantage is that the substructure is of a simple character, and is less liable to be affected by the expansion of the brickwork. A further advantage is that it enables the hot air to be still more satisfactorily distributed amongst the heating-flues.

Figs. 10, 11 and 12 (plate xv.) show longitudinal and cross-sections through the latest Koppers regenerator-oven and figs. 7, 8 and 9 (plate xiv.) similar sections through the former type of regenerator-oven. The working of the two systems is identical in

all respects, and differs only in the arrangement of the regenerators. The lettering in the two plates is accordingly the same, and the following description can therefore be taken as applying to either construction.

The air for combustion flows along the passage-ways, A, at the front and back of the ovens, and thence it passes into the regenerators through the inlets, B. In the regenerators, the temperature of the air rises to 1,000° Cent. (1,832° Fahr.). The highly heated air passes out of the regenerators into the vertical heating-flues through the openings, C. The purified gas from the bye-product plant is returned to the ovens by the mains, D, running along the whole length of the ovens on each side. Branch supply-pipes, H, conduct the gas into the gas-distributing channels, E, which are situated directly beneath the oven-walls; thence it passes through the gas-nozzles, F, into each vertical flue, where it ignites with the hot air entering through the passages, C, previously referred to (fig. 13, plate xv.). A jet is therefore formed on a level with the oven-floor in each of the heating-flues of the oven-chamber, in which respect it will be seen that the heating is identical with that of the waste-heat oven already described.

The employment of regenerators renders it necessary to reverse the heating-process after a period of time, usually about 30 minutes; and the heating-flues are divided into two sections, so that combustion can take place alternately in each half of the oven-wall. When the gas is burning in one half of the wall, the products of combustion pass up the flues and enter the top horizontal flue, G, whence they make their way down the flues in the other half of the oven-wall, and enter the regenerator through the same passages, C, by which the air is admitted to the flues when the direction of combustion is reversed. On issuing from the regenerator, the waste-gases pass into the flue leading to the chimney, after having given up their heat to the chequer-work of fire-brick.

It should be here pointed out that the same means of regulating the combustion in each separate flue and of obtaining access to the flues, are provided as in the case of the waste-heat oven (figs. 1, 2 and 3, plate xiii.); and the oven therefore possesses the same advantages as regards uniform heating and easy regulation.

It has been stated by interested parties that the walls which divide the regenerator-chambers in the Koppers new system,

having to support the ovens and the superstructure, are of insufficient strength owing to their being in a highly heated condition. It should therefore be mentioned here that the total sectional area of the walls is two-thirds of the whole surface upon which a battery of ovens is built. The walls in no case would be subjected to a greater temperature than 1,100° Cent. (2,012° Fahr.); and, as the walls in a cool state are easily capable of supporting a load 100 times the weight that they have to bear, it is abundantly evident that they will be more than amply strong enough to carry the load at the temperature stated.

It might, furthermore, be pointed out that the cubical contents of the new regenerator-chambers are from three to four times that of the ordinary construction; and that, notwithstanding this great increase in capacity, there is, if anything, less chance of heat being lost by radiation owing to the protected position in which they are placed.

Mention has been made that the employment of separate regenerators for each oven enables the supply of air and the chimney-draught to be better regulated than is possible with the old form of regenerators. On referring to figs. 7, 8 and 9 (plate xiv.) it will be seen that there is a regulating damper over the passage leading from the regenerator-chambers to the air-distributing channel. This damper has to be set to serve the dual purpose of regulating the admission of air when the ovens are burning in one direction, and of regulating the chimney-draught when the ovens are burning in the reverse direction. It is not possible to effect a satisfactory regulation of both the air and the draught by means of only one damper.

Figs. 14, 15, 16 and 17 (plate xvi.) show the new means of regulation, as also the arrangements for reversing the combustion. Figs. 14 and 15 show, respectively, longitudinal and transverse views of the gas and air-supply fittings on the side of the oven where the gas is burning; whilst figs. 16 and 17 show the corresponding arrangements on the other side of the ovens where the waste-gas is passing to the chimney. The gas is supplied to each oven by the branch pipes, H, which are each provided with a regulating-cock, K, as well as with a second cock, K_1, fitted with a lever. All the levers are attached to one of the wire-ropes, L_1, which latter communicate with the automatic changing-gear. The air is

admitted to each oven by means of the cast-iron damper-fitting, M, which also serves to conduct the waste-gases to the chimney-flue, U. These dampers are each fitted at the top with a slide, N, which are like the levers of the gas-cocks, all connected to the second wire-rope, L_2; and the whole is so arranged that, when the automatic changing-gear operates, the gas-cocks and damper-slides on one side of the battery are closed simultaneously with the opening of the corresponding parts on the other side of the battery. When the gas is burning on the side of the ovens as shown in figs. 14 and 15, the air-damper is open, and the air passes into the regenerator in the direction indicated by the arrows, the main chimney-damper, P, being closed. A little below the damper-slide there is a second slide, R, which can be set in any desired position, and serves to regulate the quantity of air required for each oven. When the gas is burning on the opposite side of the oven, as shown in figs. 16 and 17: that is, when the waste-gases are passing to the chimney, the gas-cocks and air-dampers are closed, but the main chimney-damper, P, is opened. The waste-gases are therefore drawn through the cast-iron damper-fitting, M, into the chimney-flue, U, in the direction indicated by the arrows. At the base end of the cast-iron fittings there is a third slide, S, which can be set in any desired position to regulate the draught on each oven. It will, therefore, be seen that, by the new arrangement, the quantity of air for each oven and the chimney-draught on each oven can be separately regulated, which is not possible with ovens working with the older form of regenerators. A very disadvantageous feature has thus been removed in the new system.

The automatic changing-gear is a simple clockwork arrangement, and is placed at one end of the battery of ovens. It is electrically operated, and requires the least possible attention. It may be added that the gear is so designed that should anything fail to act, an electric alarm is set in action which does not stop until the gear is again at work.

A discovery of more than ordinary importance has recently been made by Mr. Koppers, in regard to the regeneration of the air for combustion and the utilization of the waste-gases. It was found by observation and experimental tests that the heat of the waste-gases could not be reduced in the regenerators below a certain temperature, no matter of what capacity they were

made; and the result of calculations showed that the whole of the heat in the waste-gases could not be extracted by means of regenerators. Mr. Koppers ascertained that this was due to the air only being regenerated, the gas being admitted in a cool state. The proportion of gas is from one-sixth to one-seventh of the quantity of air, and consequently the volume of the waste-gases is about 16 per cent. greater than the volume of the air that it has to heat up. A loss of heat therefore took place by passing the whole of the waste-gases through the regenerators, and in the latest construction of the Koppers ovens means have been introduced to enable a portion of the waste-gases to be drawn off in a hot state for boiler-firing purposes. On referring to fig. 10 (plate xv.) a vertical flue, T, in the centre of the heating-flues will be seen. By means of this flue a portion of the hot waste-gases passes into the central flue, V, beneath the ovens, and is conducted to the boilers. A sliding-brick is placed at the top of the vertical flue, by means of which the quantity of waste-gases to be drawn off can be regulated. The reduced volume of the waste-gas which passes into the regenerators is sufficient to heat up the chequer-work of bricks to the same maximum temperature as when the whole of the waste-gases is passed through the regenerators; and the air will accordingly be heated to the same degree when subsequently passed through, the only difference being that the temperature of the waste-gases on entering the chimney is reduced to a lower degree than when the whole of the waste-gases pass through the regenerators.

It will be gathered from the foregoing description that the new construction enables about 16 per cent. of the hot waste-gases to be saved at the expense of the gases passing into the chimney. The air being raised to the same temperature as in the older construction, no more combustible gas is required for heating the ovens; and consequently the same amount of surplus gas is available. As already stated, the quantity of surplus gas from the Koppers regenerator-oven amounts to from 45 to 55 per cent. of the total quantity evolved from the coal. The gas being in a combustible form, can be conducted almost any distance, and can be utilized for any purpose for which ordinary town illuminating-gas can be used. There is, therefore, no necessity for erecting a special range of boilers in close proximity to the ovens, as is necessary with waste-heat ovens.

Gas-engines.—The great advantage of recovering the surplus heat in the coal in the form of a combustible gas is that it can be employed for generating power in gas-engines, which enables about three times the power to be derived from it that can be obtained by consuming it under steam-boilers, or that can be generated by the hot waste-gas from waste-heat ovens. The surplus gas from a coal of average composition is sufficient to produce a continuous supply of from 50 to 60 horsepower per oven. Another great advantage which combustible gas possesses over

FIG. 20.—NÜRNBERG GAS-ENGINE OF 1,200 HORSEPOWER, BARGOED COLLIERY.

hot waste-gas is that the former can be stored so long as it is not required; whilst the latter must be used on the spot directly it is produced, and cannot be employed for any other purpose than boiler-firing. At most collieries, little power is required to be produced during the night-time and on Sundays; and at such times hot waste-gas would be lost, whilst combustible gas, on the other hand, could be stored in gas-holders and consumed during working hours.

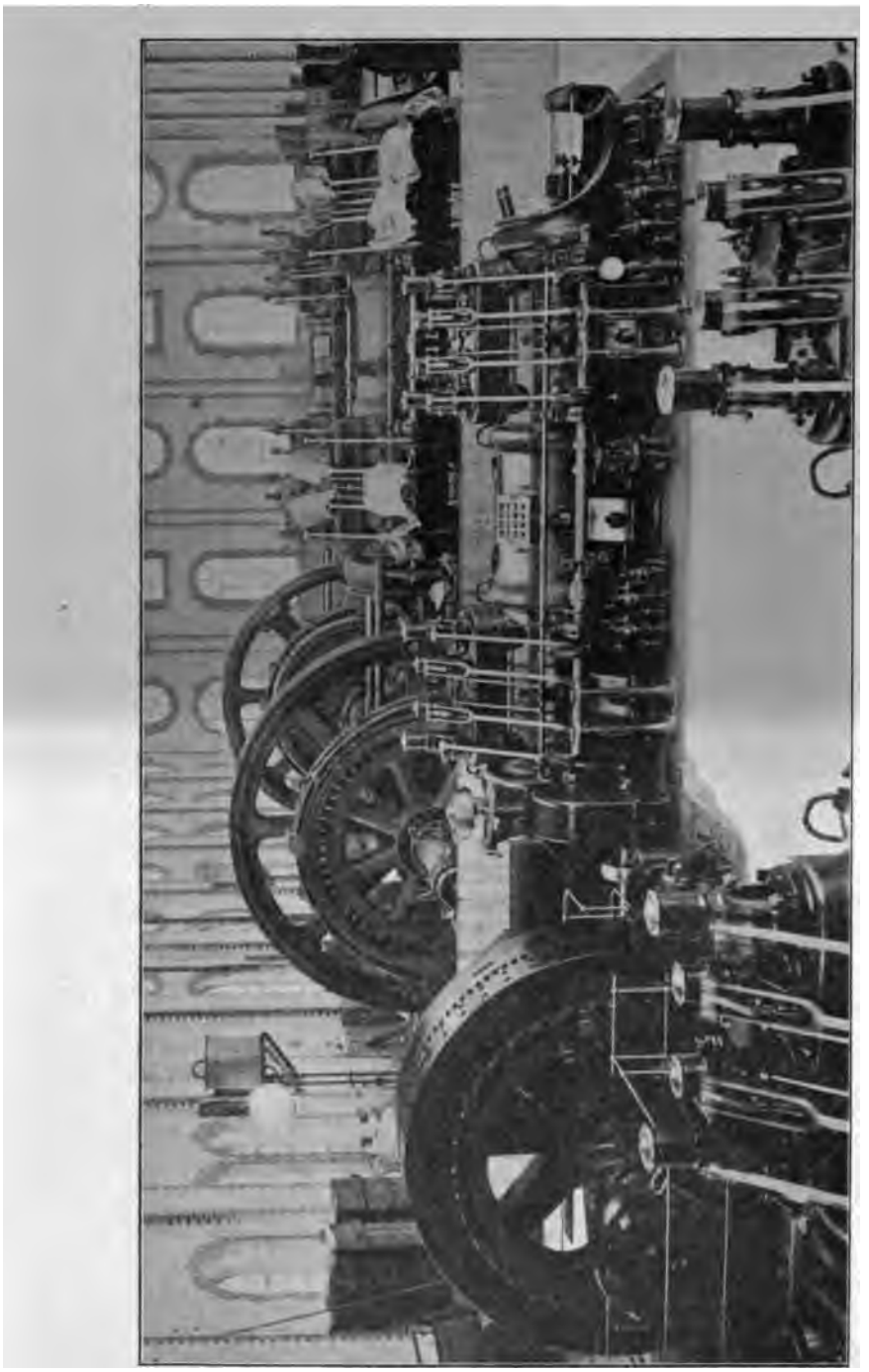

FIG. 21.—GAS-ENGINE POWER-STATION AT ARDA COLLIERY.

Great progress has been made in recent years on the Continent in the design of large gas-engines, and at a number of collieries in Germany large gas-engine power-installations have been put down in connection with coke-oven plants. Indeed, the great waste of power which formerly took place at coke-oven plants, through employing the surplus gas for boiler-firing, is responsible in a great measure for the development of the gas-engine. At a number of Koppers coke-oven plants erected in Germany and in this country, large gas-engine central-power stations have been installed. As an example of the extent to which gas-engines are employed on the Continent, an interior view is given (fig. 21) of the gas-engine power-station at the Anna colliery of the Eschweiler Mining Company, near Aix-la-Chapelle. At this colliery, there are six batteries of Koppers regenerator-ovens, totalling 342 ovens, and the power-station is designed for the production of 16,000 horsepower from the surplus gas. At present, engines having a capacity of 9,400 horsepower are in operation, whilst others are under construction.

Until recently, gas-engines of high power were viewed with great disfavour in this country, as it was generally supposed that they could not be made to drive electric generators running in parallel with each other. This was the case at one time, but difficulty in this direction is no longer experienced. At two of the pits of the Rheinpreussen collieries, situated near Homberg, Germany, two large gas-engines have been driving, for a considerable time past, three-phase generators of about 1,300 kilowatts capacity. The engines are situated several miles apart, and no trouble is experienced in getting them to work, not only in parallel with each other but with a steam-engine generating-set at a third colliery. At the Rheinpreussen collieries, it may be added, there are five batteries of Koppers ovens, totalling 225 ovens, and the surplus gas is employed partly for driving the gas-engines.

Conclusion.—In conclusion, reference should be made to the results obtained from the Koppers ovens. As the output of coke per oven depends to a great degree upon the character of the coal and is also dependent upon the sectional area of the oven itself, the results obtained from any particular plant should not be taken into account. Generally speaking, however, the output of

coke, free from breeze, made from coal of average coking quality as raised in Westphalia and the Rhineland, is about 5·2 tons per oven per day, so that a battery of 50 ovens produces about 1,800 tons of large coke per week. The yield of bye-products similarly is greatly dependent upon the character of the coal; but it is claimed for the Koppers oven that, owing to the uniform heating of the walls and to the fact that the zone of the greatest heat is at the bottom of the oven and therefore remote from the point where the gases pass out at the top of the oven and where the volatile constituents would be decomposed by great heat, a higher yield of residuals is obtained than in other systems where similar conditions do not prevail.

Before closing this paper, attention should be drawn to the great progress which the Koppers oven has made, since it was first brought out a little over four years ago, indicating clearly that the oven possesses advantages of more than ordinary character.

The CHAIRMAN (Mr. James Cope Cadman) said that the subject of bye-products played a most important part in the successful working of collieries, and would do so to an even greater extent in the future.

Mr. L. T. O'SHEA said that Mr. Kochs' paper was exceedingly comprehensive with regard to many points of importance as to the manner in which Koppers ovens were conducted. In the Koppers oven, and others of similar construction, an attempt had been made to solve the great difficulty not only of the distribution of the gases into the flues, but also that of the air used for combustion. It was necessary in order to secure the proper combustion of any gas that the proportion of air required to burn that gas should be carefully regulated. An attempt had been made to do this in the Koppers oven, and he thought that in this respect a considerable advance had been made. The pre-heating of the air for combustion deserved consideration, from the point of view of the use to which the gases were to be applied. If the waste-gases from the combustion-flues were to be used for generating steam, they should be as hot as possible, when they reached the boilers, in order to generate sufficient steam for use in the bye-product plant; whereas if the generation of power in an internal com-

bustion-motor was the object in view, the waste-gases from the combustion-flues could not be used, but the surplus of combustible gas was important. Consequently, if the waste-gases were used for generating steam, the pre-heating of the air was not desirable, because the gases, which came away from the combustion-flues, would be left in a hotter condition than if some of the surplus heat was utilized before it passed to the boilers; but if surplus combustible gas was required it would be considerably increased by pre-heating the air. He thought that Mr. Kochs was perhaps not altogether giving sufficient credit to the advantage which might be received from the thickness of the partition-walls between the ovens, when double flues were used. He (Mr. O'Shea) did not think that the question of the storage of heat was of the first importance; but he did think that double heating-flues probably utilized the heat in each oven to better advantage. The thick partition-walls carried the weight of the superstructure, and thinner oven-walls could then be used, which allowed the heat to be conducted more quickly through the walls. The small experience that he (Mr. O'Shea) had had in dealing with bye-product ovens had led him to notice how very large an amount was expended annually in repairs; and that, he thought, was largely due to the fact that the least fusible material was not employed in Great Britain for the erection of the oven-walls. He thought that more attention should be devoted to the selection of infusible bricks, because the intense heats that were obtained and the local heating that occurred suddenly, without proper attention on the part of those who had the care of the ovens, entailed a considerable amount of expense in the matter of repairs. Both the papers were valuable, because it was only by such papers that the members could obtain an idea of the construction of the ovens, and were enabled to compare the relative simplicity of different ovens. Bye-product ovens were largely increasing both in number and in variety, and it was a matter of considerable difficulty to say which was the best.

Mr. J. J. Prest (Horden collieries) said that the difference between Koppers ovens and other bye-product ovens appeared to be primarily in the adoption of vertical flues, and the manner in which the regenerative system had been scientifically worked out. The adoption of the regenerative coke-oven provided a

large percentage of consumable gases, and these could only be utilized efficiently in internal-combustion engines. Therefore, unless it was proposed to utilize the waste-gases in this manner, the regenerative system had better not be adopted. Many large installations of bye-product ovens and recovery-plants had been erected, within the last few years, at costs up to £100,000 or more; but, whether the return on the large capital-expenditures involved was satisfactory or otherwise, one could never definitely ascertain. Estimates of the probable amount of profit could be obtained in abundance: but figures giving the actual results were required. After careful consideration of the whole question, his firm had decided to erect an experimental plant of 70 beehive coke-ovens at one of their collieries, as it was considered that a larger commercial return would be obtained from them than from the erection of bye-product coke-ovens at this particular place, and under the special conditions prevailing.

Dr. J. A. Roelofsen (Middlesbrough) said that Mr. Kochs stated that "the construction of horizontal-flued ovens will not permit of more than three or four jets being employed at each end of the oven; and it is quite evident that the walls cannot be so equally heated as the walls of vertical-flued ovens. . . ."* He might state that in some horizontal-flued ovens there were twelve burners for each individual oven; and combustion in the horizontal-flued oven did not take place in a short space, as Mr. Kochs indicated, but travelled as a luminous flame the entire length, 33 feet, of the oven-flue. This was effected by the proper regulation of the air-admission, and, if necessary, one could make some of the flame come back in the next flue; consequently the heat along the length of the oven was uniform. Mr. Kochs stated that "dark places" occurred,† he (Mr. Roelofsen) supposed, in the case of Koppers ovens. This was caused, as far as he knew, by some of the nozzles of the Koppers ovens closing and not being so accessible as was implied in Mr. Kochs' paper. At any rate, whatever the cause might be, it was easy to avoid dark spots in ovens when the gas-admission was under perfect control by hand from the outside. Mr. Kochs said that "in horizontal-flued ovens, furthermore, the top flue is heated to a high degree,

* *Trans. Inst. M. E.*, 1907, vol. xxxiii., page 399.

† *Ibid.*, 1907, vol. xxxiii., pages 401 and 404.

and it is generally admitted that this is a disadvantageous feature, as the great heat has the effect of decomposing the gases of distillation. . . ."* This latter was quite true, but he maintained that the horizontal-flued oven was particularly suitable for avoiding the creation of excessive heat at the top of the oven, inasmuch as heating took place in horizontal strata so to speak, and, by regulating the gas-admission in each horizontal flue, that particular stratum of the oven could be kept cool or hot as was desired. For practical purposes it was, as everyone admitted, necessary and desirable that all parts of the oven should be uniformly heated, and that no part should be overheated; and this was done every day in horizontal-flued ovens. Mr. Kochs stated that in the Koppers oven the top portion was kept from 400° to 500° Fahr. cooler than the bottom portion;† and, if this were so, he failed to see how that could be called uniform heating. It was also stated that the division-wall was absolutely necessary in horizontal-flued ovens, otherwise the ovens of that sort would not be strong; but this was not so. He had a battery of 100 Huessener ovens which had been at work on the Continent for 20 years, and were at work at the present day. They had never had division-walls, and yet during that time they had been making coke and had given such good results that the expenditure on repairs during the last 10 years of their life had only been between ¼d. and ½d. per ton of coke made. This showed that it was not absolutely necessary to use division-walls in horizontal-flued ovens. After making many experiments over many years, the Huessener oven had, however, finally adopted the division-wall, although, as Mr. Kochs had correctly remarked, it extended along the whole length of the oven-battery and made the structure more expensive. For this reason it naturally handicapped them in competing with the builders of coke-ovens without a division-wall. The Huessener oven would discard the middle wall, which caused greater capital outlay and more ground-space to be covered, if it were not believed that there were substantial advantages to be gained from its adoption. It had been stated that the value of division-walls had been under-estimated: he agreed that it doubled the number of flues round the ovens. It was well known that, during the last stages of coking, the charges in the oven did not require such an amount of gas as a fresh

* *Trans. Inst. M. E.*, 1907, vol. xxxiii., page 399.

† *Ibid.*, 1907, vol. xxxiii., page 400.

charge; and if there were no division-wall, it was not possible to check the heat on the oven, which naturally became hotter because it was older in coking time. Furthermore, as had already been pointed out, the division-wall carried the superstructure of the oven, which was of the greatest importance. It relieved the oven-walls of the heavy weight on the top of the oven and enabled the walls to be made thinner. Without going any further into a theoretical discussion, it was desirable to get practical figures of everyday work. The figures for a battery of 60 Huessener ovens, now in their seventh year of work without interruption in the county of Durham, working with ordinary Durham coking coal, containing about 30 per cent. of volatile matter, were as follows: The cost of repairs to these 60 ovens was only about ¼d. per ton of coke, and during the 6½ years that they had been at work, only six ovens had been relined. The ovens were built of British material; and, although the oven was of German origin, it had not been found necessary to go abroad for refractory fire-bricks. There was no lack of good fire-resisting fire-clay in this country; and the only difficulty was to get fire-brick-makers to work accurately to dimensions, and to produce bricks of perfect shape. There was no need to go to Belgium or Germany for material, and if brick-makers would study the nature of their fire-clay, and make proper allowances for shrinkage, they could produce a brick of good shape and perfect dimensions. Mr. Kochs stated that, in Westphalia, the Koppers oven made 5·2 tons of coke per oven per day, or 1,800 tons of large coke from 50 ovens per week. He thought that this result was obtained from Westphalian coal containing about 20 per cent. of volatile matter; could Mr. Kochs give the production of coke from coal containing 30 per cent. of volatile matter, as in the case of Durham coal, or 32 per cent. as in the case of South Yorkshire coal? It would also be interesting to know the cost of repairs, during the four years that Koppers ovens had been on the market.

Mr. Emerson Bainbridge said that Mr. Prest's remarks were all the more interesting, as that gentleman was never behind in finding out the most modern improvements in mining engineering, and therefore they were to be regarded with all the more weight. His own experience, however, had been that the

proprietors of new plants were only too anxious to point out the advantages of such plants, and they would no doubt take the opportunity of doing so. There had been marvellous progress in Germany in the utilization of the waste-gases from coke-ovens, and it justified one in expecting that in a few years there would be many collieries working their entire plant, without steam, by gases produced from bye-product ovens. He was afraid that the multiplication of bye-product ovens might lead to such a diminution of the value of the materials produced as to make the advantage rather less important than at first it appeared to be; but, as the demand seemed to continue, the values might be maintained.

Mr. R. Sutcliffe (Barnsley) said that for several years he had been using compressed-air plant, and he felt that the present method was a wasteful one. He believed that it was partly due to the piston of the steam-cylinder travelling at the same speed as the piston of the air-compressing cylinder; and, in order to get a high efficiency from the steam-cylinder, the piston of the air-cylinder was overrun. He had had some experience in the use of gas-engines, and, after having used steam-engines for many years, he had come to the conclusion that the former was the most economical when used for power-purposes in connection with gas produced at a colliery.

Mr. Isaac Hodges said that a life for bye-product ovens of 6½ years, with negligible repairs, was almost unprecedented in his own knowledge, and must be largely due to the state of dryness in which the coal went into the ovens.

Dr. J. A. Roelofsen said that washed coal was used, containing 12 per cent. of water.

Mr. Hodges said that he had never heard of a bye-product coke-oven standing for 3 years, and 6 years was unprecedented. He had found from experiments that the lime in the water acted as a flux on the fire-bricks, and produced extensive honeycombing. Dr. Roelofsen must have used exceedingly pure water at the ovens under his charge, or they must have been built with exceptionally good bricks: he thought that he had used the same bricks, and therefore it was difficult to correlate the facts. After 10 years' experience of bye-product ovens, he had found

that the bye-products of a comparatively new oven were much larger than those obtained from an oven in a poor state of repair. Horizontal flues, which were so much a feature of the earlier bye-product ovens, had almost entirely disappeared; the chief reason had not been mentioned by Mr. Kochs, namely, the effect of the wind-pressure on the horizontal flues, causing that part of the oven to be rapidly cooled; and for that reason he had changed to vertical-flued ovens. The flues of the ovens under his charge had no middle wall; he believed that the superstructure was too heavy a burden for the flues to carry in normal times, especially after being slightly weakened. However, he agreed that the middle wall, if not absolutely necessary, was a great convenience in the case of repairs. The ideal oven was one which would not fail because it had a very heavy superstructure to carry; the fabric should remain intact, so that it could be relined at leisure, making the cessation of coking a limited matter, and reducing at the same time the cost of repairs.

Mr. J. Kenneth Guthrie (Leeds) wrote that the Otto Company, in Germany, introduced the regenerative principle about 20 years ago, and for many years enjoyed almost a monopoly with their regenerative coke-ovens. About 1895, however, coke-ovens of the waste-heat type came to the front as rivals; and, realizing that this type of oven had some striking advantages, more especially in simplicity of construction and greater provision of steam for colliery-purposes, the arrangement of heating from below the oven as introduced by Mr. Hilgenstock had been applied mainly in waste-heat ovens, but, of course, they were equally fitted for regenerative purposes. The Otto Company had erected many ovens of this type in Germany, etc.; but in Great Britain there was a strong preference for the waste-heat type, owing, no doubt, to the fact that gas-engines did not enjoy the same popularity in this country as on the Continent.

Mr. H. W. Seymour (Leeds) wrote that Mr. Kochs' paper was very interesting, in so far as it showed the most recent construction of the Koppers oven. The comparison drawn, however, between that oven and horizontal-flued ovens was naturally to the disadvantage of the latter, and faults were shown that were non-existent in any modern system of horizontal-flued ovens. So far as Great Britain was concerned, the latter system was

meeting with increasing favour, and as many, if not more, were being erected as those of the vertical-flued type. It was probably on account of the vertical-flued system being built wholly by German companies that they had found such favour in Germany. Mr. Kochs had been misinformed as to the largest number of jets possible in a horizontal-flued oven being three or four on each side:* it was quite possible to use as many as eight or nine jets on each side. The same effect, however, as a large number of jets, was obtained in a simpler way, by admitting the air for combustion at various points. In practice, it was found that as regular a heat was obtainable as with the vertical-flued system. Intense overheating of the top-flue was not a feature of horizontal-flued ovens; in most types the top part of the oven could be controlled from comparative coldness to an intense heat, without affecting the heat of the lower part of the oven: this feature not being possible with the Koppers type of oven. Judging from the number of inventions intended to obviate this defect, the excessive heating of the top part of an oven appeared to have been a difficulty met with to an even greater extent in vertical-flued than in horizontal-flued ovens.

The experience of many builders proved that the solid central partition was a most valuable and indispensable feature, as it facilitated repairs, two ovens only being partly affected instead of four; and it considerably reduced the period of coking. In the case of two plants working side by side, one with and the other without a central wall, the flues of the latter appearing to be hotter than the central-wall plant, the production was only 22 tons of coke per week as against 26 tons. The increase in the length of a plant built with central partition-walls would certainly not exceed 20 to 25 per cent., and the heat-radiation, especially with ovens surrounded by air-flues, would be even less than with the single-flued vertical type. It was usually found in the course of time that the tops of single-flued ovens sank to a greater extent than in the case where the great weight of the superstructure was supported independently of the highly heated thin oven-walls; it was to be noted also that a thinner oven-wall could be used where this weight was supported by a solid central wall.

It might be thought from Mr. Kochs' remarks that no surplus

* *Trans. Inst. M. E.*, 1907, vol. xxxiii., page 399.

gas was available in the case of a non-regenerative oven; but in the case of Yorkshire coal, at least 33 per cent. of the gas was available, plus all the steam required for working the plant. It was a question, therefore, whether it was worth the capital-charge and complication to work a regenerator for a gain of 5 or 10 per cent., especially where steam had to be made for working the plant. This point was well exemplified in the case of one regenerative plant, where the coke-oven boilers were hand-fired with coal. He (Mr. Seymour) acknowledged the theoretical value of many of the ingenious contrivances explained by Mr. Kochs, but so far as practical working was concerned he would like comparisons to be made with other than German coal. The English equivalent was apparently not greater than 20 to 25 tons of coke per week; and both in quality and quantity of products this could be easily equalled by any modern type of horizontal-flued coke-oven at a lower capital-outlay than with a plant such as the one in question. Further, the ease of inspection and adjustment at every stage of the working in a horizontal-flued oven proved of paramount importance in practice; and, from the results obtained at many plants in this country, it did not appear as if they were gained at the expense of the oven—considered as a producer of saleable coke and bye-products. The working results of the plant described by Mr. Kochs did not warrant, in his opinion, such claims of superlative excellence over and above other systems having the same end in view.

Mr. A. Victor Kochs, replying to the discussion, wrote that he was obliged to disagree with the view expressed by Mr. O'Shea that the provision of a division-wall enabled the heat in each oven to be utilized to better advantage, as it was an incontrovertible fact that heat was lost through radiation by greatly increasing the length of the battery, which could not possibly be avoided if a central wall and double flues were adopted. Whereas in single-flued vertical ovens, as pointed out in his paper, any cooling effect, which a freshly charged oven might have on its neighbour, would simply be an exchange of heat and would have not the slightest influence on the ultimate result. Mr. O'Shea further stated that the dividing wall served to support the superstructure, and the walls of the oven could therefore be made thinner.

To a certain degree this was correct, but there was a limit to the thinness of the oven-walls; and, as a matter of fact, the walls of vertical-flued ovens were no thicker than those of horizontal-flued ovens arranged with a dividing wall. A large number of Koppers ovens had been built with side-walls, not exceeding 3 inches thick. If the walls were made thinner, leakage of the gases of distillation into the heating-flues would be very considerable, especially after the ovens had been working for some time. The strength of the walls of Koppers ovens lay mainly in the flue-partitions, 5 to 6 inches thick, and only to a comparatively small extent in the side-walls, 3 to 3¾ inches thick. The total weight of the superstructure, including the gas-collecting equipment and three loaded corves, carried by each single wall, amounted as a maximum in the Koppers oven to no more than 32 tons, and as the sectional area of the walls at the weakest point was 35 square feet, the load per square foot was rather less than 1 ton. Fire-bricks, such as were employed in Koppers ovens, had a crushing strength equal to 150 to 200 tons per square foot, and an easy calculation would show that the walls were 150 to 200 times as safe at the weakest part. This was, of course, when the ovens were cold, but it was, nevertheless, abundantly clear that the factor of safety would be more than ample when the ovens were in a heated condition. The sectional area on a line drawn horizontally through the heating-flues was 52 square feet, and this surface would support a load of several thousand tons; and it was quite obvious that there was no likelihood of such a wall giving way through the comparatively light superincumbent weight. Further, the single vertical-flued wall of the Koppers oven was even stronger than that of a horizontal-flued oven with two sets of flues and a dividing wall, 14 inches thick. The whole of the weight of the superstructure in a horizontal-flued oven rested on the dividing wall, and the horizontal sectional area of this wall was no more than 40 square feet as compared with 52 square feet in the Koppers oven. In addition, the weight of the superstructure of a horizontal-flued oven was very considerably more than that of a single vertical-flued oven, which was due, of course, to the ovens being further apart. The area of the wall being less and the weight to be carried being greater, it necessarily followed that the construction was considerably weaker

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would here emphasize the fact that the main advantages of the
Koppers oven were the same, whether the oven was designed to
work with or without regenerators. The special feature of the
Koppers oven was the uniform heating of the walls, combined
with easy accessibility of all flues for regulation and inspection,
which was attained to a remarkable degree of perfection. The
egenerators were only necessary adjuncts, when the surplus heat
the coal was required to be produced wholly in the form of a
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ote from the battery of ovens, or where power was required to be
nerated by means of gas-engines, in which latter case about
times the power would be derived that could be obtained
raising steam with the gases, or that could be generated by
waste-heat from non-regenerator ovens. The information
to the commercial results to be obtained from a bye-product
en-installation was rather difficult to supply, as there were
many factors that affected the economy and working of the
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that only three or four heating-jets were employed at
a horizontal-flued oven. This was an inadvertence,
uld have stated that there were three or four jets at
each end of each set of heating-flues. He (Mr. Kochs) noted that the Huessener oven was heated at six points at each end of the oven, that was twelve points altogether; and, as it was more particularly in respect to the distribution of the heating that the Koppers oven was distinguished from other systems, he would draw particular attention to the fact that each Koppers oven was heated by sixty to seventy gas-jets. It would therefore be apparent that there was far more likelihood of uniform heating being attained with a large number of jets distributed along the length of the oven, than by comparatively few jets at the ends only. As regards the "dark places" referred to in his paper, he must express surprise that Dr. Roelofsen should take exception to this term, as it was a technical expression universally employed to indicate the comparative intensity of the heating of the walls. In horizontal-flued ovens, there were only twelve really "bright places," that was at each point where the gas was admitted; and no one could deny that it was theoretically and practically impossible for a flame, 33 feet long, or even half that length, to be as hot at the end after giving up its heat to the charge of coal, as it was at the point of combustion. This was the reason why the building of horizontal-flued ovens had been abandoned in Germany, and in his (Mr. Kochs') opinion admitted of no argument. Dr. Roelofsen also referred to the statement that there was a difference of 400° to 500° Fahr. between the temperatures of the top and the bottom of the oven, and he was at a loss to see how that could be called equal heating. Dr. Roelofsen must be well aware that uniform heating was required along the length of the oven, and not so much in the height; that was, that the greatest heat should be applied opposite the bottom of the charge, lessening towards the top, but

than that of the Koppers oven. It was, therefore, quite fallacious to claim that the dividing wall was an advantage as regarded strength.

The fire-bricks employed in the construction of Koppers ovens were made of a special composition which had been found, from experience, to be most suitable for the purpose. This material could be obtained in England, and the only trouble experienced was in getting the bricks made to the exact sizes and shapes required. Brickmakers were, however, now taking much greater care in the manufacture of the bricks, with the result that complaints as to size had seldom to be made.

The supposition expressed by Mr. Prest that the difference between the Koppers oven and other systems was primarily in the regenerative principle was incorrect; and, as there appeared to be a general misapprehension in this regard, he (Mr. Kochs) would here emphasize the fact that the main advantages of the Koppers oven were the same, whether the oven was designed to work with or without regenerators. The special feature of the Koppers oven was the uniform heating of the walls, combined with easy accessibility of all flues for regulation and inspection, which was attained to a remarkable degree of perfection. The regenerators were only necessary adjuncts, when the surplus heat in the coal was required to be produced wholly in the form of a combustible gas for firing existing boilers situated at a point remote from the battery of ovens, or where power was required to be generated by means of gas-engines, in which latter case about 3 times the power would be derived that could be obtained by raising steam with the gases, or that could be generated by the waste-heat from non-regenerator ovens. The information as to the commercial results to be obtained from a bye-product oven-installation was rather difficult to supply, as there were so many factors that affected the economy and working of the ovens, which varied in different parts of the country. The principal factor was the quality of the coal together with the amount of residuals which it contained, whilst other factors were the value of the coke produced, the length of time required for carbonization, the percentage of alkaline salts contained in the coal (which had the effect of corroding the oven-walls and rendered repairs frequently necessary), etc. The size of the plant had also much to do with the return, as the first cost and the labour-cost

did not increase proportionately with the capacity. Any figures therefore which might be given would probably be misleading; but, generally speaking, it could safely be stated that a moderate-sized plant of 60 ovens costing, say, £60,000, would yield a return of from 30 to 40 per cent., after making full allowance for repairs and redemption of capital.

Dr. Roelofsen had pointed out an error in his paper, wherein he stated that only three or four heating-jets were employed at each end of a horizontal-flued oven. This was an inadvertence, and he should have stated that there were three or four jets at each end of each set of heating-flues. He (Mr. Kochs) noted that the Huessener oven was heated at six points at each end of the oven, that was twelve points altogether; and, as it was more particularly in respect to the distribution of the heating that the Koppers oven was distinguished from other systems, he would draw particular attention to the fact that each Koppers oven was heated by sixty to seventy gas-jets. It would therefore be apparent that there was far more likelihood of uniform heating being attained with a large number of jets distributed along the length of the oven, than by comparatively few jets at the ends only. As regards the "dark places" referred to in his paper, he must express surprise that Dr. Roelofsen should take exception to this term, as it was a technical expression universally employed to indicate the comparative intensity of the heating of the walls. In horizontal-flued ovens, there were only twelve really "bright places," that was at each point where the gas was admitted; and no one could deny that it was theoretically and practically impossible for a flame, 33 feet long, or even half that length, to be as hot at the end after giving up its heat to the charge of coal, as it was at the point of combustion. This was the reason why the building of horizontal-flued ovens had been abandoned in Germany, and in his (Mr. Kochs') opinion admitted of no argument. Dr. Roelofsen also referred to the statement that there was a difference of 400° to 500° Fahr. between the temperatures of the top and the bottom of the oven, and he was at a loss to see how that could be called equal heating. Dr. Roelofsen must be well aware that uniform heating was required along the length of the oven, and not so much in the height; that was, that the greatest heat should be applied opposite the bottom of the charge, lessening towards the top, but

equally along the length of the oven, so that the charge of coal would be subjected to exactly the same temperature throughout its length, and so that the top part of the charge would not be too intensely heated.

In making the statement that there was on the Continent a battery of 100 Huessener ovens arranged without division-walls, which had been at work for twenty years and had cost very little for repairs, Dr. Roelofsen should have pointed out that the side-walls were made correspondingly thick to compensate for the absence of the division-walls; and the effect of these thick walls was the prolongation of the period of coking, as the heat could only pass through very slowly. These ovens, he understood, required 48 hours to burn off. It was easily understood, therefore, why the single-flued wall was finally discarded in the Huessener oven. At any rate, it was quite clear that, if a single horizontal-flued wall would stand the length of time stated by Dr. Roelofsen, a single vertical-flued wall, being a much superior and stronger construction, would last very considerably longer. The figures given by Dr. Roelofsen as to the cost of repairs at the Huessener plant in Germany, and also those given of the plant in Durham, must have been miscalculated, as he had been informed by a former manager of the first-named plant, who was now in charge of a large installation of Koppers ovens, that the walls of the ovens required renewal, every two to three years, notwithstanding that the ovens were worked at a comparatively low temperature: the coking period being, as already stated, 48 hours. In regard to the Huessener plant in Durham, Mr. C. Lowthian Bell* had stated that the cost of repairs taken over 12 months, after the ovens had been working three years, amounted to 1·60d. per ton of coke. It was difficult to reconcile this figure with that given by Dr. Roelofsen, namely, ¼d. per ton of coke, after the plant had been working for seven years.

Dr. Roelofsen was correct in stating that, during the last stages of coking, the charges of the oven did not require the same amount of gas as in the earlier period of coking; but, after mentioning that without a division-wall it was not possible to check the heating, he should have added that this was unnecessary and

* "The Manufacture of Coke in the Huessener Oven at the Clarence Iron-works, and its Value in the Blast-furnaces," by Mr. C. Lowthian Bell, *The Journal of The Iron and Steel Institute*, 1904, vol. lxv., page 188.

was never done with single-flued ovens, being only rendered necessary by the provision of a division-wall. It never happened that two adjoining ovens were charged at the same time, and consequently there would always be a more or less considerable difference in the coking stages of any two ovens. As a result, when one oven was ready, its neighbour would require heating for a further period of time. The heat produced in the flues automatically passed to the charge, which was incompletely carbonized, whilst the oven which contained the completed charge would take only a comparatively small portion of the heat. It would be obvious that this would not be possible if a division-wall were placed between the ovens, and towards the later period of coking the heat on such ovens must be checked, otherwise overheating, with possibly disastrous consequences, would occur. The single-flued walls of the Koppers oven, on the other hand, could not only be maintained at the same high temperature throughout the coking period, but could be forced in the second half of the coking period without fear of overheating, and it was for this reason that a greater output of coke was obtainable from the Koppers oven than from any other system working under equal conditions.

As mentioned in his (Mr. Kochs') paper, the output of coke was dependent upon the character of the coal, the size of the ovens and the working conditions. The amount of moisture in the coal also affected the coking period, whilst the time of coking was extended if the coal were charged into the oven in the form of a compressed cake. Nearly all the Koppers ovens erected in England were from 22 to 24 inches wide, and with one exception the coal was compressed in every plant. The output of coke from ovens working with compressed coal was 28 tons per week from Durham coal, and 26 tons per week from South Yorkshire coal, whilst the output from ovens working with uncompressed coal was 35 tons per week. In the latter case, however, the coal contained only 20 per cent. of volatile matter. A reduction in the width of the oven would enable the output to be considerably increased; and, in comparing the yields of several different types of ovens, the width should be taken into account. The reduction in the width had the disadvantage, of course, of producing short pieces of coke.

He (Mr. Kochs) had been asked to state the cost of repairs

of Koppers ovens, and again in this regard he must say that the cost of repairs depended greatly upon the working conditions, which varied considerably at different plants. The great bulk of Koppers ovens which had been erected during the last four years, that was, since the oven was introduced, had not cost 1d. in repairs. The heating of the ovens, as would have been seen, was so uniform that the oven-walls were subjected to a much smaller variation in temperature than in any other system, and the wear-and-tear was therefore correspondingly less. In cases where the coal was charged into the ovens in a very wet state, or where the coal (or the water in the coal) contained alkaline salts, the wall-bricks suffered severely; and any oven working under such conditions would require frequent repairs, especially those systems which were not uniformly heated. He could safely state that the cost of repairs of a battery of Koppers ovens, working under normal conditions, would be lower than that of other systems, and further, that no serious repairs would be necessary during the first four or five years. After this period of time, it would probably be necessary to renew the lower courses of bricks in the oven-walls.

The CHAIRMAN (Mr. J. C. Cadman) moved a vote of thanks to Mr. A. V. Kochs for his interesting paper. He might mention that in some districts, particularly in North Staffordshire, slack-coal, which was formerly almost given away, was now washed and made into a valuable coke, through the introduction of bye-product coke-ovens.

Mr. ISAAC HODGES seconded the vote of thanks, which was heartily carried.

The Rev. G. M. CAPELL read the following paper on "The Application of Duplicate Fans to Mines":—

THE APPLICATION OF DUPLICATE FANS TO MINES.

By the Rev. G. M. CAPELL.

The general idea has hitherto prevailed that little or any advantage could be gained by using two fans, on one upcast-shaft, as compared with running one of them singly at the same speed. There are records in the *Transactions** which appear to confirm this idea, that whether one or two fans are run at an equal speed, the result will practically be the same; but in all those past experiences the fans were not placed on the mines with a view to their working together. On thinking over the question, the writer came to the conclusion that the disposing of two fans on a mine, either a single or a double inlet, in such relative positions to each other that the passing of the air would correspond to the action of a double-inlet fan, was possible, and would produce the results of a double-inlet fan with other advantages.

The positions of the fans, A_1 and A_2 could be arranged so as to resemble the action of a double-inlet fan, by using the parting of the air-drifts between the inlets (figs. 1 and 2, plate xvii.). Another condition must be considered, namely, that in double-inlet fans, A_1 and A_2 (fig 3), with a central dividing-plate, each fan is practically a separate machine, so far as each inlet is concerned. There is, however, a great difference between a double-inlet fan and two separated fans, namely, that the double-inlet fan, working in a single casing, has a constant condition of water-gauge in that casing; whereas two fans, working in duplicate, might have a variation of the water-gauges in the casing, arising from small difference of speed, or in those variations which affect air-currents in coming to the inlets of a fan. This is remedied by a regulating passage, with a valve connecting the two fan-cases in the new arrangement. With this arrangement for balancing the case-pressures, the two fans can be relied on to act as if

* "A Duplex Arrangement of Centrifugal Ventilating Machines," by Mr. W. Cochrane, *Trans. Inst. M. E.*, 1891, vol. ii., page 483.

they were running in one casing. The equalizing or regulating passage, F, is shown with its valve, *g*, placed between the two fans (figs. 1, 2 and 3, plate xvii.).*

In working a fan by tri-phase current, now so much in use, a difficulty presents itself, namely, the great loss of power at week-ends and other off-days, by being unable to regulate in a simple manner the speed of the fan and the consumption of current. In the application of two single-inlet fans, say, 15 feet in diameter, to a mine, at 220 revolutions per minute, the two fans would each produce 250,000 cubic feet of air per minute at 6½ inches of water-gauge in the inlet-passage; and this would unite in a common water-gauge, beyond the division between the inlets, that is, in the main drift, D. A model of the arrangement shows very clearly, when one motor-driven fan is stopped and the automatic drift-door is closed, by the minus or suction water-gauge of the working-fan, still running at the same speed, and using the same power as when creating 6½ inches of water-gauge, that the single fan will pass 66 per cent. of the volume of air produced by the two fans, working together at the same speed, at 2·8 inches of water-gauge. Consequently, the speed of a tri-phase motor need never be changed in these duplicate fans, and the cost of working the fans can, in a minute, be reduced to half, or even less than half, at pleasure, while 66 per cent. of the full daily circulation of air is secured in the mine. The difficulty of reducing the speeds of tri-phase motors first turned the attention of the writer to this new application of duplicate fans.

It may be of interest to state that the actual cost of the two duplicate fans is very little more than that of a single fan to do the same maximum work. It will doubtless be seen that great advantages will result from applying this system especially to new mines, where one fan will probably be sufficient to ventilate the mine for, say, 10 years; and the other fan can be added, as the water-gauge of the mine, the length of the air-ways and the rubbing-surface increase. The two fans can then be worked together in unison, and produce the higher water-gauge required, with a larger volume than that produced by the single fan.

The reason why one fan running alone at the same speed as the two fans produces up to 75 per cent. of the volume produced

* British patent, April 28th, 1906, No. 9,952; and United States patent, November 6th, 1906.

by the two fans, on this duplicate system, is very simple. If the volume, say, 400,000 cubic feet per minute at 6 inches of water-gauge, is produced by two fans at equal speeds: then, if 300,000 cubic feet per minute be passed, the water-gauge, due to 300,000 cubic feet under the same mine-conditions, will be reduced from 6 inches to 3·375 inches, and the horsepower in the air will be 163·6. When one fan is producing half of 400,000 cubic feet at 6 inches of water-gauge, the horsepower in the air is 189, leaving a wide margin for loss of useful effect due to the large volume per revolution passing through the fan under the lower water-gauge, because the water-gauge produced by the fan at its normal speed is transformed so largely into volume: a fact well known to engineers who have tested fans on a mine, under varying water-gauge conditions.

Duplicate fans, for the largest volumes and high water-gauges, are now in construction; and, when they are running, the formulas relating to their work will be compiled so as to enable them to be easily adapted to the varying conditions of mines.

The Chairman (Mr. C. C. Leach) asked what results would be obtained by the two fans, where one fan delivered the air through the other.

The Rev. G. M. Capell said that, in such a case, the same effect was obtained as in a series pump. He had calculated the anticipated results of the two fans long before they were made: he had then worked the details into a practical form, and it was possible to get almost any desired result at varying water-gauges. The duplicate fans as shown in figs. 1 and 2 (plate xvii.) had not yet been tested on a mine; but an electrically-driven plant was in course of erection.

Mr. Robert Clive (Doncaster) asked what would be the effect if one fan was run at a higher speed than the other.

The Rev. G. M. Capell said that the fans would be electrically driven, so that the two fans would run closely to the same speed. The speed would have to be reduced at once, should there be any great differences of speed. The fans would work efficiently, if the difference of water-gauge between the two fans did not exceed ¼ inch; but a difference of water-gauge exceeding ¼ inch

would cause air to be drawn from one fan to the other, and then the balancing air-passage and its valve, between the fan-cases, would come into action.

Mr. J. C. B. Hendy (Etherley) wrote that some years ago he made experiments with duplicate Waddle fans at Pleasley colliery.* He (Mr. Hendy) did not believe in running two fans on the same fan-drift, in regard either to efficiency or to economy. The Pleasley fans were not run together, the idea being simply to have a spare fan always in readiness.

Mr. D. Murgue (St. Etienne, France) wrote that the ideas expressed by Mr. Capell seemed very judicious. Undoubtedly, in theory, the volume of air furnished by two fans revolving at precisely the same speed could not be greater than the volume furnished by a single fan. But, in practice, it was otherwise, as the friction of the air in the various parts of the fan must be taken into account, for it caused a diminution in the volume which the fan was capable of producing. Now, when two fans were at work, only half the volume was produced by each, diminishing therefore by a half the total loss of useful effect due to friction, and increasing consequently in a noticeable proportion the volume of air passed through them. This increase was especially noticeable when the two fans were of small dimensions and were working on a mine with a large orifice, such as were most British pits. But in a mine with a small orifice, such as were very frequent in France and Belgium, two fans of large size would hardly yield a volume of air notably greater than that yielded by a single fan. It was, therefore, quite possible that in a mine with a large orifice, two fans being set in motion at a constant speed by tri-phase current, 66 per cent. of the normal volume of air would be obtained with a single fan and at much less cost.

Mr. Sydney F. Walker (Bath) said that he would like to get down to the bed-rock of the whole matter. As he understood the results, each of the fans exhausted 200,000 cubic feet of air at 6 inches of water-gauge, that was, together they produced 400,000 cubic feet of air at 6 inches of water-gauge; and singly, each fan produced 300,000 cubic feet of air at 3§ inches of water-gauge; but, when running together, the two fans produced a water-gauge of 6 inches, that was, 3 inches each.

* *Trans. Inst. M. E.*, 1891, vol. ii., page 535.

The Rev. G. M. CAPELL said that when the two fans were running together the water-gauge was 6 inches; but when one fan was running alone the water-gauge was 3§ inches.

Prof. G. R. THOMPSON (Leeds) asked (1) whether the statements contained in the paper were taken from actual tests or from theory; also (2) what disadvantages were expected from two ordinary fans working at similar speeds on a mine, and what advantages would ensue on raising the valve in the passage between the cases of the two fans. The chimneys were connected together at the top, through the medium of the outside air, and he could not imagine that any advantage would be obtained by connecting points where the chamber was expanding and the air was losing its velocity. Whatever the general opinion had been as to the effect of two fans on one mine, the results obtained would depend upon the relative sizes of the fans and the resistance of the mine. If the resistance offered to the passage of a given volume of air through the fan was great compared with that of the mine, then two fans in parallel placed on one mine would give a largely increased result; but, if the resistance of the fan was small compared with that of the mine, then two fans in parallel placed on the mine would practically give no better result than one fan. Was it a fact, when one of the two motor fans was stopped, that the other fan running at the same speed and using the same power would pass 66 per cent. of the volume produced by the two fans working together; and consequently, with the duplicate arrangement, the cost of running one fan at the week-ends instead of both (when the motor was of the constant-speed type) would be half or even less, while 66 per cent. of the normal output of air was obtained? It would be interesting to know how the results were obtained, and the conditions of their application, because it was generally understood that the water-gauge produced by a fan was proportional to the square of the speed of the tips of the blades, and was constant for a constant speed. Now, whether one fan was working alone, or whether it was working in conjunction with another fan, the water-gauge produced by that fan would be constant if the speed was constant; and, as the energy absorbed depended upon the water-gauge produced and upon the volume of air passing through the mine, if the velocity remained constant, the water-gauge and the work would

increase in proportion to the volume of air passing through the fan. One would therefore expect that a fan, driven by a three-phase motor running at a constant speed, would probably produce a volume, such as that stated by Mr. Capell, somewhere about 66 per cent. of the total produced by two fans; the water-gauge in the fan-drift would be lower: the extra water-gauge produced by the fan, owing to the constant speed, being absorbed in overcoming the resistance of the fan to the passage of the increased volume of air. Mr. Capell also suggested that his system could be applied "to new mines, where one fan will probably be sufficient to ventilate the mine for, say, ten years; and the other fan can be added, as the water-gauge of the mine, the length of the air-ways, and the rubbing-surface increase."* He (Mr. Thompson) ventured to think that anybody who put this system into practice would meet with failure, under the conditions premised. The fans would probably have to be placed in series, thus adding the water-gauges, and not in parallel, adding the quantities.

Mr. J. W. FRYAR (Eastwood) said that Mr. Capell's proposed application of duplicate fans might afford the best results when the fans were electrically driven, but he was not so sure that any advantages would be obtained in the case of steam-driven fans. He (Mr. Fryar) was rather an advocate of the use of electricity, but he had not yet reached the point where he would use electricity to drive a mine-fan. Mr. Capell had suggested that, in his system, one fan would be sufficient to ventilate a mine, say, for the first ten years, and after that period had elapsed and if the requirements of the mine demanded it, a second fan would be erected; but no one could forecast what conditions might exist at the end of ten years. A considerable saving might be effected by selecting a fan of suitable dimensions for a new colliery. Very often, a large fan was erected, and for the first ten years it was working at from 20 to 50 per cent. of its full load, and the efficiency would only be 30 to 40 per cent. instead of 60 to 66 per cent. From a purely commercial point of view, if a small fan were erected, the cost would be small, the cost of working would be small, and the efficiency during the first ten years would be 60 or 70 per cent. instead of 30 to 40 per cent. He was sure that the savings in ten years resulting from the erection of a small fan would pay for the cost of a large fan and new plant

* *Trans. Inst. M. E.*, 1907, vol. xxxiii., page 432.

at the end of the ten years; and then the new fan should be able to supply the requirements of the mine for another ten years. He, however, thought that it would be economical, so far as steam-driven fans were concerned, to erect a small plant at first and to replace it by a larger one, say, at the end of ten years.

Mr. Emerson Bainbridge (London) agreed that it would be economical to erect a fan, of small dimensions, which would give a high useful effect for the first ten years of the life of the mine; but, if it were of proper capacity for the ventilation of the mine for these ten years, it might afterwards be used as a duplicate or reserve fan for the large permanent fan. Engineers advocated the erection of a duplicate fan in the hope and idea that it might never be used; and if an accident happened to the large fan, the small fan, originally erected, could be used. He did not agree with the suggestion that they should look forward to the second fan breaking down at the end of twenty years or so. He thought that it was quite possible to so arrange a colliery-plant, that the first and small fan would work for ten or fifteen years, and at the end of that time, when they knew their exact conditions, a large permanent fan (erected before being needed) would be available.

Mr. W. H. Patchell (London) said that it often happened that an engineer, who might preferably desire to drive a fan by steam, had to resort to electricity, through force of circumstances. When a colliery was being worked electrically, the saving due to electric working was greatest on a plant which was worked intermittently, such as haulages; and, when current was being generated by the owners, it was necessary to work electrically the plant which ran long hours, so that the load-factor on the generating-station was kept up. The total cost of production was then low and the total saving was great, although if considered on their own merits there might appear to be a loss on working the fans electrically. He (Mr. Patchell) asked whether Mr. Capell had done anything more than experiment with the model of the interesting arrangement exhibited. Results from a full-sized installation would be most interesting, and he felt sure that all the members wished that Mr. Capell's hopes might be realized.

Mr. A. J. KENNEDY (Whitwood collieries) said that by adopting the arrangement suggested by Mr. Capell, a source of great waste might be overcome. Since Prof. T. Guibal introduced his centrifugal fan, it had been the practice to erect a large fan at a new mine; but, at the same time, it could not be used economically for many years, and in a large number of cases, the fans were never worked at the speed for which they were designed during their whole life at the mine. The uncertainty about a large number of mines, as to how long they would work or how the output might be altered, was sufficient to give Mr. Capell's scheme very great weight. Mr. Capell also laid stress on the prevention of waste at week-ends, a point well worth considering; and when the power absorbed by a large fan, doing very little work and driven by a correspondingly large engine, was considered, the waste was very apparent. With regard to electric driving, the advantages were very evident. He (Mr. Kennedy) knew of an electrically-driven

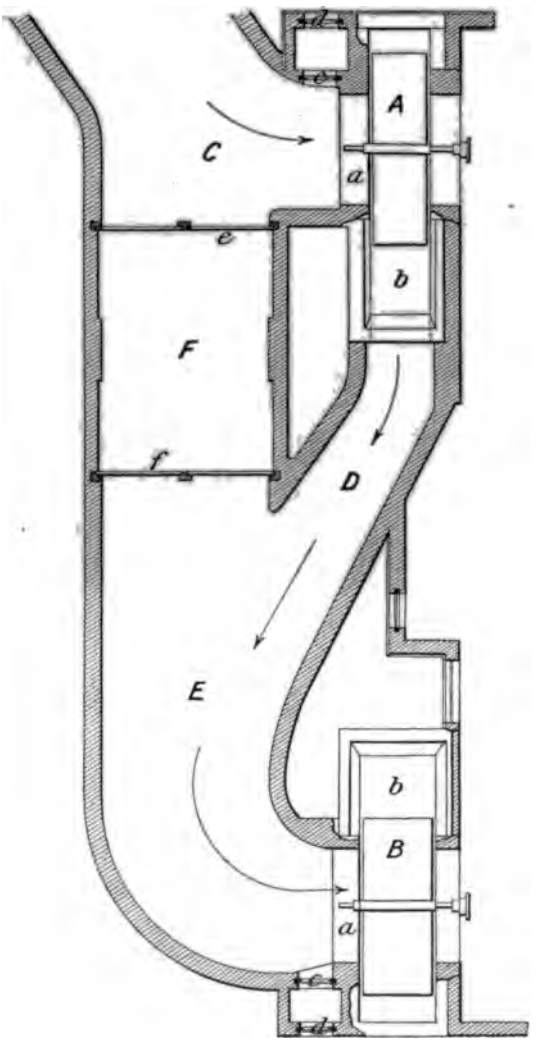

FIG. 4.—DUPLICATE CAPELL FANS, WITH SINGLE-INLETS, WHITWOOD COLLIERIES.
SCALE, 16 FEET TO 1 INCH.

fan, running at full speed, and, as the mine was only in its infancy, the inlet of the fan was partly closed in order to reduce the quantity of air passing through it.

An alternative to Mr. Capell's scheme had been devised by Mr. Isaac Hodges, of the Whitwood collieries. The fans were designed for a mine which had reached its maximum output; and, as the workings got further away from the upcast shaft, a higher water-gauge would be required to pass the same quantity of air along the increased length of roads. In order to effect this result as economically as possible, two fans had been erected to run in series (fig. 4). The first Capell fan, A, 16 feet in diameter and 4½ feet wide, was designed to produce a water-gauge of 6 inches; and the second Capell fan, B, 15 feet in diameter and 5½ feet wide, was designed to produce a water-gauge of 3 inches. The second fan, B, had been working some time, and was producing all the air that was required at present; but, when required, the first fan, A, would be started and would pull the air directly from the shaft at a water-gauge of 6 inches, passing it on to the second fan, B, which would produce a water-gauge of 3 inches. Consequently, the first fan, A, would only have to produce (6−3=) 3 inches of water-gauge, and a great saving of power would be effected. Whether these results would be realized in actual practice, however, remained to be proved.

The Rev. G. M. CAPELL, replying to the discussion, said that his paper was a statement of results founded on theory and proved by experiments. The pipe, F, and the valve, *g*, between the casings, were intended to produce equilibrium between the pressures in the two fan-casings, thus producing the conditions of a divided fan, with two inlets, working in one casing; and the nearest comparison would be the connection of two air-chambers by a connecting-pipe. He would suppose that both fans, working together, showed 65 per cent. of manometric efficiency; and, on stopping one fan, the volume dropped to 66 per cent. of the total passed by the two fans. The one fan produced this volume, running at the same speed as when passing half the original volume at the water-gauge required by the mine; but, the volume being reduced, the single fan dealt with it at the lower water-gauge of 2·8 inches. The equivalent orifice of the mine being unchanged, the lower water-gauge, due to only 66 per cent. of the original volume passing, had now to be produced by the single fan. He (Mr. Capell)

only knew of two conditions which would produce the same water-gauge when the fan was running at the same speed:—(1) When the initial water-gauge of a fan was tested, with the mine closed entirely from the fan; or (2) when a fan was tested on the same equivalent orifice. When working in series, each duplicate fan would produce equal water-gauges at the same speed, and each would deal with the volume of air that they would pass normally at that water-gauge. When working in parallel, each fan would produce its normal water-gauge, in its own drift; this water-gauge would be united at the main drift beyond the division, and would be the water-gauge required to pass the required volume under the equivalent orifice of the mine. The present-day and future developments of a mine, of course, depended on circumstances; and where more seams were worked, more air was required, at an enhanced water-gauge.

Mr. H. W. HALBAUM (Birtley) wrote that Mr. Capell had stated one proposition that was sound, and another that seemed untenable. By duplicate fans he understood Mr. Capell to mean two fans of similar design, having practically equal efficiencies, both with respect to the production of pressure and to the passage of volume.

With regard to Mr. Capell's sound thesis that, if one of the duplicate fans were stopped whilst the other continued to run at the same speed, the reduced volume of air would be greater than half of the original volume, the question: How much greater? would naturally occur to most engineers. The following solution depended on the theory of the equivalent orifice. If one fan be stopped, the power expended on the passive resistances would be reduced by a half, since half of the belt-and-journal friction, etc., would be done away with, the speed being the same as before, when both fans ran together. Then as to the volume of air. Let the total pressure produced in either case be H, then $H = h + h_0$: h being the pressure expended on the mine-resistance; and h_0, the pressure expended on the resistance of the fan or fans to the passage of the volume. Let a be the equivalent orifice of the mine; and $o/2$ the orifice of passage for each fan; then the sum of the fan-orifices is o. Ignoring unnecessary numerical constants, which affect both cases alike:

$$a = \frac{V}{\sqrt{h}}; \text{ and } o = \frac{V}{\sqrt{h_0}}.$$

The squared quantities being, at present, more convenient, the equations may be written:

$$a^2 = \frac{V^2}{h}; \text{ and } o^2 = \frac{V^2}{h_0}: \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

V being the volume of air when both fans are running. Since h equalled the pressure expended on the equivalent orifice of the mine, a; and h_0 equalled the pressure expended on the sum of the fan-orifices, o; it is clear that $H = h + h_0$; that is, the pressure expended on a and o combined. Hence, the joint orifice of the mine and fans together, or the effective orifice of the whole arrangement is m; and:

$$m^2 = \frac{V^2}{H} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Substituting the value of $(h + h_0)$ for H, and then substituting the values of h and h_0 given by equation (1), it followed that:

$$m^2 = \frac{V^2}{\frac{V^2}{a^2} + \frac{V^2}{o^2}};$$

but as V had the same value on all the orifices a, o and m, the expression can be reduced to:

$$m^2 = \frac{a^2 o^2}{a^2 + o^2}, \text{ and } m = a \frac{o}{\sqrt{a^2 + o^2}}.$$

It was obvious, when both fans were running, that:

$$m = a \sin\left(\tan^{-1}\frac{o}{a}\right), \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

or m equalled a multiplied by the sine of an angle whose tangent was equal to o divided by a. Let that angle be ϕ, then:

$$m = a \sin \phi \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

But, from equation (2), m equalled V divided by the square root of H; and combining this with equation (4), it followed that the value of V, when both fans were running, was:

$$V = a \sqrt{H} \sin \phi \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (A)$$

When one fan was stopped and the other continued to run, the original effective orifice m was reduced to n; the orifice of passage was reduced from o to $o/2$; and a remained the same as before, since the mine conditions were unaltered; and H was the same value as before, since the speed was constant. But the volume V originally obtaining was now reduced to v. By precisely the

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$$m^2 = \frac{V^2}{H} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Substituting the value of $(h + h_0)$ for H, and then substituting the values of h and h_0 given by equation (1), it followed that:

$$m^2 = \frac{V^2}{\frac{V^2}{a^2} + \frac{V^2}{o^2}};$$

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It was obvious, when both fans were running, that:

$$m = a \sin\left(\tan^{-1}\frac{o}{a}\right), \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

or m equalled a multiplied by the sine of an angle whose tangent was equal to o divided by a. Let that angle be ϕ, then:

$$m = a \sin \phi \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

But, from equation (2), m equalled V divided by the square root of H; and combining this with equation (4), it followed that the value of V, when both fans were running, was:

$$V = a\, \sqrt{H} \sin \phi \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (A)$$

When one fan was stopped and the other continued to run, the original effective orifice m was reduced to n; the orifice of passage was reduced from o to $o/2$; and a remained the same as before, since the mine conditions were unaltered; and H was the same value as before, since the speed was constant. But the volume V originally obtaining was now reduced to v. By precisely the

same reasoning as that adopted above to find the value of V, the following formula was obtained for the altered conditions. The effective orifice of the new arrangement was:

$$n = a \sin\left(\tan^{-1}\frac{o}{2a}\right).$$

Let the new angle be θ, then:

$$n = a \sin\theta \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

and also:

$$n = \frac{v}{\sqrt{H}},$$

which, by combination with equation (5), gave for the value of v when only the one fan was running:

$$v = a\sqrt{H}\sin\theta \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (B)$$

And since $a\sqrt{H}$ was the same for both cases, the ratio of V and v was:

$$\frac{V}{v} = \frac{\sin\phi}{\sin\theta} = \frac{\sin\left(\tan^{-1}\frac{o}{a}\right)}{\sin\left(\tan^{-1}\frac{n}{2a}\right)} \quad . \quad . \quad . \quad . \quad (C)$$

Now, except in the infinitesimal arcs of mathematicians where arc, sine and tangent were all equal, there was no case where the sine and the tangent varied at equal rates. But the angles ϕ and θ were always very large arcs. It was indeed sufficiently well known that no fan could give a satisfactory efficiency on any mine unless o was at least equal to $2a$. And probably Mr. Capell, who had a keen eye for visible efficiency, had seldom, if ever, of his own free will, installed a fan on a mine apart from the conditions that o should be at least 3 or 4 times a.* Hence the value of the tangent of the angle ϕ was seldom less than 2 and seldom more than 4. If tan ϕ equalled 1, then o equalled a, and half the pressure must be expended within the fan itself, and such a fan could obviously never yield an efficiency so large as 50 per cent., since 50 per cent. of the aerodynamic power would be spent within the fan, and a proportion of the total power on the passive resistances. Table I. showed the effect of the ratio o/a upon the problem stated by Mr. Capell. The table, read in horizontal lines, was self-explanatory, and showed that accord-

* "Ventilation of Mines," by Mr. M. Walton Brown, *The Colliery Manager's Pocket Book*, 1891, page 274.

ingly as the original value of o/a (when both fans were running) varied from 1 to 5, the volume v obtained by the one fan would vary from 63 to 95 per cent. of the volume V obtained by both.

TABLE I.—VOLUME OF AIR PRODUCED FROM VARYING FAN-ORIFICES AND MINE-ORIFICES.

No.	$\text{Tan } \phi = \frac{o}{a}$	$\text{Tan } \theta = \frac{o}{2a}$	$\text{Sin } \phi = \text{V}$	$\text{Sin } \theta = v$	$\frac{\text{Sin } \phi}{\text{Sin } \theta} = \frac{\text{V}}{v}$	$\frac{v}{\text{V}}$
1	1	0·5	0·707	0·447	1·58	0·63
2	2	1·0	0·894	0·707	1·26	0·79
3	3	1·5	0·949	0·832	1·14	0·88
4	4	2·0	0·970	0·894	1·09	0·92
5	5	2·5	0·981	0·928	1·05	0·95

The unsoundness of Mr. Capell's second statement was easily demonstrated. He stated that "the speed of a tri-phase motor need never be changed in these duplicate fans, and the cost of working the fans can, in a minute, be reduced to half, or even less than half, at pleasure, while 66 per cent. of the full daily circulation of air is secured in the mine."* In this, Mr. Capell seemed to be under a misapprehension, as the cost would vary as the power expended. The power expended, apart from the portion absorbed by the passive resistances, would vary directly as the total pressure, H, multiplied by the volume, V, or, v, as the case might be; and not as the reduced mine-pressure, h, multiplied into v, as Mr. Capell appeared to suppose. The speed being constant, the total pressure, H, was constant, however much the relative values of its two terms, h and h_0, might be made to fluctuate. Since H was constant, the total aerodynamic power, and its cost, would vary directly as the volume of air. If the speed were constant, the cost could be reduced to one-half only by reducing the volume by one-half. This could be done by a regulating screen in the fan-drift, or by changing the gear of the fan. But the question naturally suggested itself: Why not have recourse to the regulating screen, or the differential pulley in the first instance, instead of putting down a second fan? The regulating door, brattice, or screen referred to, appeared to furnish the most simple, the cheapest and the most practical solution of the difficulty which had suggested to Mr. Capell the erection of duplicate fans.

* *Trans. Inst. M. E.*, 1907, vol. xxxiii., page 432.

Mr. R. L. Galloway (Bridge of Allan) wrote that Mr. Capell's chief aim in suggesting the employment of two fans, instead of one, seemed to be to obtain facilities for slowing down the ventilation at week-ends and other idle days. In the interests of the safe working of fiery mines, the adoption of such an arrangement with such an object could not, in his (Mr. Galloway's) opinion, be too strongly deprecated. When mechanical ventilators first began to come into use, one of the advantages claimed was that a greater degree of exhaustion might be employed with a view to draining the mine of gas when the men were out. It was perhaps doubtful whether this had ever been practised, but unfortunately, in many cases, the opposite course had been followed. The speed of the ventilator had been slackened, and accumulations of gas allowed to form in the workings, thus predisposing the mines to explosion on the resumption of operations. If the history of these disasters were examined, it would be found that they had ever been most rife after periods of cessation from work; not only was the slowing-down of the ventilation during periods of cessation from work fraught with danger, but he (Mr. Galloway) believed that it was illegal. He did not wish it to be understood that he disapproved of duplicating ventilators; but both should be of full power, and the ventilation should be constantly maintained at its normal rate at all times, whether the mine was at work or not. This was a paramount consideration of safety in the working of fiery mines.

The Chairman (Mr. C. C. Leach) said that Mr. Capell had drawn particular attention to the advantage of incurring only a small outlay at the beginning of the life of a mine. The use of electricity was advocated, but he hoped that the members would remember that steam-engines had been vastly improved of recent years. He moved that the best thanks of the members be accorded to Mr. Capell for his clever paper.

Mr. M. Walton Brown seconded the resolution, which was unanimously approved.

DISCUSSION OF MR. SAM. MAVOR'S PAPER ON "PRACTICAL PROBLEMS OF MACHINE-MINING."*

Mr. SAM. MAVOR, referring to Prof. C. Latham's question regarding the height of the cut†, wrote that where the undercut was not deep, say, 3 to 3½ feet, it was usually desired, if the holing was made in coal, that the height of the cut should be the least possible in order to save the coal; and if the cut was made under the coal, it should also be the least possible (unless additional height at the face was required) in order to keep down the amount of dirt to be handled. Where, however, the undercut was deeper it might be desirable to increase the height of the cut (whether made in the coal or under it) in the following cases:—(*a*) Where a hard coal parts in large blocks from the back of the cut and sits down without breaking up; (*b*) where the pavement rises, and reduces the clearance for the coal to drop after being undercut. In such cases, considerable advantage had frequently been observed in the tapered cut made by the bar machine: the greater height at the front of the cut permitting the coal to fall forward and facilitating its breaking up.

With regard to the use of inbye air-compressors, Mr. W. Reavell's statement‡ that he had found it possible to convey hot compressed air through covered pipes to a distance of 1,000 feet with very little fall of temperature was extremely interesting, as was Mr. Reavell's confirmation of his (Mr. Mavor's) view that substantial gain in economy would result by compressing adiabatically, conveying the hot air to the coal-cutter motor, and there using it expansively.

Certain limitations had been correctly indicated by Mr. J. S. Ward to the provision of more frequent gate-roads§, as suggested in his (Mr. Mavor's) paper. But the advantage of feeding the shaft from a large area was not apparent; and, by doing so, many of the advantages, which ought to be realized from machine-working, might be sacrificed. He (Mr. Mavor) had data relating to the working by machines of a large number of seams under 3 feet thick; and, almost without exception, the gate-roads to the faces yielding the largest and most regular outputs per machine, were less than 60 feet apart.

* *Trans. Inst. M. E.*, 1906, vol. xxxi., page 378; and vol. xxxii., pages 197, 391 and 499.

† *Ibid.*, 1906, vol. xxxi., page 440. ‡ *Ibid.*, 1906, vol. xxxi., page 441.

§ *Ibid.*, 1906, vol. xxxi., page 442.

From the point of view of the electrical design of three-phase coal-cutter motors, Mr. H. M. Hobart's advocacy* of low periodicity could not be challenged, but these machines were the resultant of compromise and concession in relation to every factor. In the case of coal-cutters of the larger sizes, 750 or 800 revolutions per minute from the mechanical point of view might be considered a suitable rotor-speed; but the diameter of these machines permitted six-pole or eight-pole windings to adapt them for the speeds named, at periodicities of 40 or 50 cycles per second. In the case of small size three-phase coal-cutters, however, there was no mechanical reason why the rotor-speeds should not be 1,000 or even 1,200 revolutions per minute; and a periodicity of 25 cycles, by limiting the speed to 750 revolutions per minute, also limited the power available from a machine of a given height. On a circuit, with 25 cycles per second, therefore, the smaller machines, which could also be wound with four poles or with six poles, were at a disadvantage in respect of power as compared with machines of the same dimensions on circuits, with 30, 40 or 50 cycles per second. In short, the machine, with 25 cycles per second, was restricted to one speed, namely, 750 revolutions per minute, whereas higher periodicities afforded a choice of increased speeds and powers.

Mr. Hobart's remarks on starting torque† were very interesting: the problem of starting torque with a simple squirrel-cage rotor was satisfactorily solved, so far as the Pickquick bar machine was concerned; but for machines of other types, which required higher starting torques, the advantage of the double squirrel-cage rotor as compared with a slip-ring rotor was worth considering.

The communication from Dr. J. R. M. Robertson‡ of New South Wales afforded some interesting glimpses of problems in coal-mining that presented themselves in that colony. The impelling motive in the adoption of machines appeared, in Dr. Robertson's case, to have been the hard necessity for reduction in costs; and it was gratifying to learn that, notwithstanding the difficulties encountered, the results of this pioneer essay with longwall machine working had been entirely satisfactory. It might be noted that the success was not immediate, nor did it

* *Trans. Inst. M. E.*, 1906, vol. xxxii., page 391.

† *Ibid.*, 1906, vol. xxxii., page 392. ‡ *Ibid.*, 1906, vol. xxxii., page 393.

seem yet to be complete. The best methods of adapting and applying the machine to the peculiarities of the seam were only arrived at by the exercise of intelligent observation and resourceful management. The seam in several respects was a difficult one, and the achievement of success in a country remote from the aid of riper skill and experience in machine working was highly creditable to those concerned. It was evident that the full advantage of the large output available from machines in that case would only be realized by the application of mechanical conveyance at the face. The adoption of the skip described by Dr. Robertson would alleviate the difficulty in respect of filling the coal, and would serve as a step towards a solution by simple mechanical means. It was satisfactory to know that the initial hostility of the men had been overcome, and it was probable that, as had occurred elsewhere, the men would ultimately exhibit a preference for employment in machine-wrought sections. The experience of Dr. Robertson, in respect of complete immunity from breakdown of the machines, was similar to that of a colliery manager, who recently stated that when he adopted machines he "expected nothing but trouble, but had had nothing but coal."

Mr. W. Bolton Shaw, in his valuable contribution* to the discussion, referred to the flywheel effect of electrically-driven coal-cutters; but apparently he had not realized the full importance of this point. In machines of the larger and more powerful sizes, the stored energy in the rotating parts was considerable; and, in machines of corresponding power, it was generally greater in the three-phase than in the direct-current type, owing to the greater diameter required to meet the exigencies of design in the former. The absence of commutators in the three-phase type gave greater license in respect of speed of rotation; and, when the periodicity of the electric supply permitted, speeds of between 900 and 1,000 revolutions per minute were not infrequent. The stored energy in a three-phase coal-cutter rotor was therefore often much greater than that in a direct-current armature, and had actually called for the strengthening of mechanical parts, which had never given trouble in direct-current machines. It was true that the three-phase motor would stop when loaded above a certain point, beyond which a direct-current machine

* *Trans. Inst. M. E.*, 1906, vol. xxxii., page 502.

would struggle on; but in case of the cutters meeting with great and sudden resistance, as when striking a large ironstone-ball when the haulage rope was short and tight, the energy stored in a three-phase rotor (it amounted sometimes to 25,000 foot-pounds) might cause breakage of a mechanical part before the machine had time to pull up.

Mr. Shaw's comparison of direct-current and three-phase motors was extremely interesting, but it could not be accepted as universally, and probably it was not generally applicable. The three-phase motors referred to must have had relatively low overload capacity which, although admittedly an advantage in the case under discussion, was not a characteristic of all coal-cutter motors of the type. The case cited by Mr. Shaw showed clearly the disastrous consequences of overdriving coal-cutters, and should serve as a warning against this practice. His (Mr. Mavor's) discouragement of the submergence of coal-cutter switches in oil was due to the difficulty of maintaining the oil-tightness of switch-boxes in seams that were not approximately level, and therefore of keeping a suitable head of oil above the sparking points. The machine-faced joints of switch-box covers were flame-tight. He was in complete agreement with Mr. Shaw's views as to the type of power-plant for coal-cutters.

Messrs W. J. Kemp and G. A. Lewis' paper on "Gypsum in Sussex" was read as follows:—

GYPSUM IN SUSSEX.

By W. J. KEMP and G. ALFRED LEWIS.

Occurrence of Gypsum.—The Sussex gypsum occurs in the Purbeck beds, found at the surface, in two or three isolated patches, in a narrow band of country lying between two great faults, running from south-east to north-west. These beds were identified as of Purbeck formation, as one of the results of the Sub-Wealden exploration-boring commenced at Netherfield in the year 1872. Although in this paper the authors are not directly concerned with the ultimate result of this historic bore-hole, it may not be out of place to mention that, through the enthusiasm and untiring devotion of the late Mr. Henry Willett, of Brighton, and with many troubles and difficulties, it was finally carried to a depth of 1,905 feet, by the Diamond Rock-boring Company, without finding any indication of the nearness of the Primary rocks.

The Sub-Wealden Gypsum Company, Limited.—Gypsum having been discovered, the next thing was to endeavour to make some practical use of the circumstance. This idea occurred to two different sets of men: one party coming from Leicestershire, hailing Mr. Bosworth as their leader; and the other from Surrey, consisting, for the most part, of directors and others, connected with the Dorking Grey Stone Lime Company. The Leicestershire party soon got to work, and sank a shaft, within about 60 yards of the experimental boring, on land belonging to Mr. C. A. Egerton. He gave every facility for the work, and granted a lease to the Leicestershire gentlemen above mentioned, who had been strengthened by the addition of one or two wellknown Sussex men. At this juncture the two rival parties met, and, after talking matters over, decided to work jointly, and formed the Sub-Wealden Gypsum Company, Limited. The company, at that period, had no thought of manufacturing plaster, as it was understood that there was an abundant market for gypsum in the lump.

The shaft, which had then reached the upper seam of gypsum, was 4 miles from the nearest railway-station, and 1 mile from the nearest available road. Consequently nothing could be done until a railway-siding had been arranged for and put in, and a tramway had been constructed to connect the siding with the shaft, over a mile away. No building-materials of any importance, or machinery of any weight, could be got to the shaft without the tramway, so there was considerable delay. However, these troubles were overcome at last, and in the year 1876 some gypsum was sent away.

Sussex Gypsum.—The working or upper seam, with which the authors have been most concerned, consists of a continuous bed

FIG. 1.—MOUNTFIELD GYPSUM-MINE, WITH HAULAGE-ROADS FROM RAILWAY-SIDINGS AND BOILING-PAN HOUSE.

of compact grey gypsum, with pockets of white. Usually there is no cleavage at all between the grey and the white gypsum, and the two kinds merge into each other more or less abruptly. The pockets of white are enclosed in and attached to the grey gypsum, and sometimes are themselves engrained with the grey gypsum, and therefore anything like complete separation of any considerable quantity of the white would be very difficult. It was one of these pockets of white gypsum, doubtless, that the drill revealed as a seam of "pure statuary alabaster." On analysis, the white gypsum is found to be absolutely pure crystallized sulphate

of lime. Some of the grey gypsum is almost equally pure; and some recent analyses average as follows:—Crystallized gypsum, 99·1 per cent.; sand and clay, 0·7 per cent.; and moisture, 0·2 per cent. In places, the grey gypsum is not of this pure character, and is found engrained with more or less calcareous shale, formed in films between the layers of crystals. The upper seam of gypsum, now being worked, varies from 4 to 7 feet in thickness. It is bounded at the top and bottom by lines of satin-spar of variable thickness. These satin-spar lines rise and fall: when the top line falls the bottom one usually rises, inclining the two lines to approach each other. They do not actually meet, however, but approach and recede without coming nearer than about 3 to 4 feet. When they are nearest together, the grey gypsum is engrained with rock, and when they are farthest apart, the grey gypsum is purest and there is more white. The roof and floor of this seam are both composed of alternate layers of calcareous shale and gypsum. Peculiar nodules of gypsum are found in the floor, varying in size from a pea to a diameter of 2 feet or more. Some of these nodules are discoid, and some of the large ones are found with a number of small nodules enclosed within them.

FIG. 2.—GYPSUM-KILNS.

There is another seam of gypsum, below the one that is now being worked, of a beautifully crystalline character. It appears to be very regular in its thickness of about 21 inches. An analysis of a specimen of it is as follows:—Crystallized sulphate of lime, 99·5 per cent.; sand and clay, 0·1 per cent.; and moisture, 0·4 per cent.

The overlying beds, as described by Mr. J. E. H. Peyton, in a paper read, in March, 1874, before the Hastings and St. Leonards Historical and Philosophical Society, are detailed in Table I.

TABLE I.—SECTION OF STRATA IN THE UPPER PORTION OF THE SUB-WEALDEN BORING, 1872.

No.	Description of Strata.	Thickness of Strata. Ft.	Ins.	Depth from Surface. Ft.	Ins.
1	Shales	17	0	17	0
2	Blue limestone ...	2	0	19	0
3	Shale	5	0	24	0
4	Blue limestone ...	2	0	26	0
5	Shale	4	0	30	0
6	Limestone	1	0	31	0
7	Shale	4	0	35	0
8	Limestone	3	0	38	0
9	Shale	4	0	42	0
10	Blue shale	16	0	58	0
11	Grey shale	3	0	61	0
12	Hard shale	14	0	75	0
13	Shale, with crystals of carbonate of lime ...	9	6	84	6
14	Grey shale	13	0	97	6
15	Greenish shales, with veins of gypsum ...	20	0	117	6
16	Impure gypsum ...	9	0	126	6
17	Pure gypsum * ...	4	0	130	6
18	Impure gypsum ...	8	0	138	6
19	Pure gypsum ...	3	0	141	6
20	Dark gypsum, impure	13	0	154	6
21	Blue shale	3	0	157	6
22	Gypsum-nodules and veins	13	0	170	6
23	Gypsum-marl ...	8	0	178	6
24	Black sulphurous marl	1	0	179	6

* Gypsum-seam now being worked.

Mr. Peyton states that under the beds of gypsum, there is a greenish sand, with nodules of chert, 21 feet thick, and below that are several veins of sulphurous shale, whilst at 328 feet, comes a grey shale (very fossiliferous) stated to belong to the Kimeridge clay. At about 480 feet from the surface, beds were found strongly impregnated with petroleum. Gypsum is often found in the mine, in the neighbourhood of faults, stained with, and smelling strongly of, petroleum. Attempts have been made to find natural gas in the neighbourhood by boring into the clay, but they have not been successful.

Plaster-manufacture.—It was soon found that, from one cause or another, very little business could be done in raw gypsum, and it was determined to manufacture plaster, etc., on the spot. The first plaster was made with gypsum broken into small pieces, about the size of a hen's egg, and baked in a Perkins oven erected for

the purpose.* This oven was heated by longitudinal tubes, running the whole length of the oven. In the manufacture of these tubes, one end was sealed by welding, and enough water was run into the tube to fill one-tenth of its length. The water was then gently heated, until the air was driven out by the steam so produced. The remaining open end of the tube was then sealed by welding, leaving a vacuum, except for the enclosed water and water-vapour. A number of these tubes were laid side by side, forming a flat series along the bottom of the oven, passing at one end through a firebrick-wall, dividing the oven from the furnace. The tubes were inclined towards the furnace-end of the oven, their lower ends forming the fire-bars. A corresponding set of tubes ran along the top of the oven, also passing through to the front of the furnace and receiving the upward heat from the fire. The water in the tubes was vaporized, and the steam carried the heat, and distributed it evenly over the whole length of the oven. The plaster made by this method was very good, and received nothing but praise from those who used it. The tremendous cost, however, of the ovens in relation to the quantity of plaster treated, and the high cost of filling and emptying, precluded the continued use of these ovens for manufacturing plaster on a commercial scale.

Ordinary plaster-ovens were then adopted, and a form of continuous kiln was used for some years with fair success.

An American plaster-dryer (a revolving-cylinder arrangement), which was said to have achieved a reputation in the United States, was at one time brought into notice, and was given a fair trial. The inventor spent some days at the works, but he was not able to make his machine a great success. The gypsum for treatment in this apparatus was broken to about the size of peas; and this, of course, entailed the making of a large proportion of dust, which could not be dealt with satisfactorily in the machine. It was necessary to keep a strong current of air moving onward through the cylinder to get rid of the steam, and this current of air carried the dust with it, distributing it over the surrounding country. This dust might have been intercepted doubtless, and deposited in a stive-room; but, as it was neither calcined nor uncalcined, it would have been difficult to utilize it profitably. A small dust-collecting chamber, attached to the apparatus,

* *Trans. N. E. Inst.*, 1879, vol. xxix., page 49 and plate ii.

proved quite inadequate. And further, the products of combustion, passed through the cylinder, proved to be objectionable.

In the meantime, a change was going on in the trade, which was relegating baked plaster, more and more, into the background. Years ago, and until nearly the time of which the writers are speaking, baked plaster had always been in demand, and boiled plaster had not been in favour. The reason of this was, that boiled plaster had formerly been made by hand-labour, the result

FIG. 3.—HOPPERS ABOVE BOILING-PANS.

being good, or bad, according to the care taken by the man who had charge of the making of it. The plaster therefore varied in quality, and could not be depended upon. By the introduction of round pans, with mechanical stirrers, boiled plaster was brought to perfection, and became liked for the regularity of its setting quality; and as it sets slowly and gives the plasterer more time for working it than quick-setting baked plaster does, it became gradually more popular in the eyes of the men who had to use it, and now boiled plaster is almost exclusively used for building work.

The modern method of producing boiled plaster is to sort, break, and grind the gypsum to powder (fig. 3). It is then run into a round pan built of firebrick, with flues under the floor, and fitted with revolving stirrers (fig. 4). Sometimes cast-iron plates cover the flues, and form the bottom of the pan, the plates nearest the furnace only being protected with a layer of fire-tiles under them. Forced draught is often used, but it is not essential. When the fresh charge gets warm it runs freely, almost like water, before the scrapers; and steam escapes from it, giving the appearance of

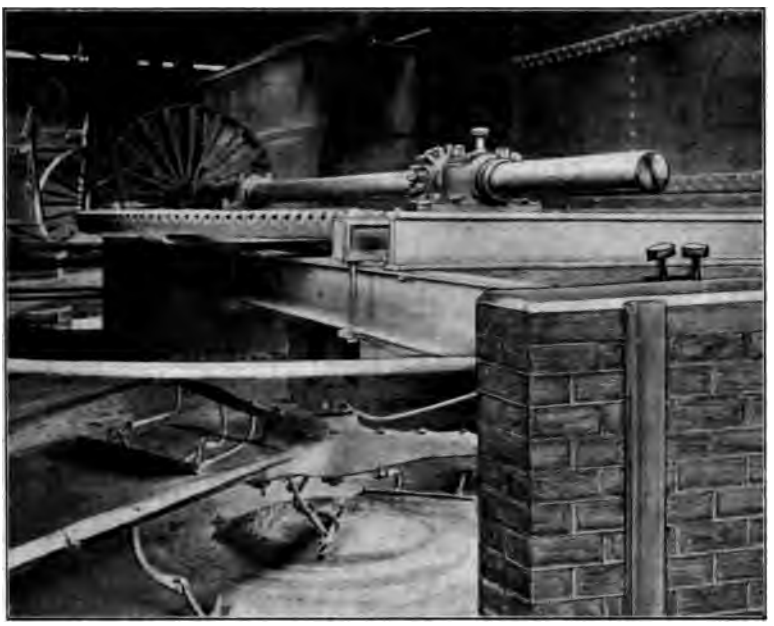

FIG. 4.—BOILING-PANS WITH REVOLVING STIRRERS.

boiling, from which the process takes its name. When the heating has gone on long enough, the liquidity of the plaster lessens and the latter gathers in front of the stirrers, showing to the experienced attendant, that it has been sufficiently heated. A door in the side of the pan is then opened and the charge swept out by scrapers which are let down for the purpose. The plaster flows into a hopper, and is elevated into another hopper for the purpose of sacking-off.

The "perfect and inexpensive" system of making plaster has yet to be devised; but, in the meantime, boiling-pans provide a

means of making excellent plaster of regular quality, much appreciated by the workpeople, who have to deal with the material after it has left the manufacturers' hands. There is undoubtedly a great deal of wear-and-tear with the furnaces and flues, and the heat at which it is found necessary to keep the floor is greater than, from theoretical considerations, would seem to be required. On the other hand, the result of calcining a charge of plaster in this way is so sure, that nothing but the grossest wilful neglect on the part of the man in charge, would be sufficient to produce an indifferent batch of plaster by this process.

There is a remarkable difference between baked and boiled plaster in their setting time. The former, when new, sets in about 6 minutes, whereas boiled plaster takes 15 or 16 minutes to set. Probably the quick setting of the baked plaster is due to its containing some particles finer than those which are produced in the boiling process. The finer particles are more easily soluble in water, and solubility is the chief factor in starting the setting action. Mr. W. A. Davis, in a paper read before the Society of Chemical Industry,* showed that the setting of plaster goes on in two stages: An orthorhombic dihydrate is formed; this afterwards passes, with some expansion, into gypsum, which is a mono-symmetric dihydrate. The two dihydrates are of the same chemical composition, but of different crystalline characters. Mr. Davis found that the first effect of heating gypsum is to convert it into the orthorhombic variety before the water of crystallization is given off. Thus there is a double series of bodies, each pair being alike in chemical proportions, but of different crystalline characters: (*a*) Insoluble anhydrite, as found in nature or obtained by heating gypsum at a red heat, and soluble anhydrite prepared by heating gypsum at a low heat, etc.; (*b*) Gypsum itself, the mono-symmetric dihydrate, and the orthorhombic dihydrate; and lastly (*c*) the half hydrate known as plaster of Paris, and the less soluble half hydrate produced by boiling gypsum in water under pressure.

Besides plaster of Paris, Keene's cement and Parian cement are made in the usual way, and a speciality called "Sirapite," is turned out in fairly considerable quantities. Sirapite, a

* "The Nature of the Changes involved in the Production and Setting of Plaster of Paris," by Mr. W. A. Davis, *The Journal of the Society of Chemical Industry*, 1907, vol. xxvi., page 727.

thoroughly calcined cement-plaster, has acquired much popularity amongst architects, as well as with builders and plasterers. It is sold cheaply, and can be used in most localities at about the same cost as that of common-lime plaster. The London Hospital, Napsbury Asylum, King Edward VII. Sanatorium, and many other similar buildings, as well as many inexpensive cottages, have been plastered with sirapite.

Gypsum as Manure.—Gypsum has been used as a manure for many years. It has been largely used in Germany for clover, etc., and in America, it is said, for all crops. Benjamin Franklin demonstrated the remarkable action of gypsum when used as a dressing for clover. Prof. James F. W. Johnston, in his *Lectures on Agricultural Chemistry and Geology*, gives many striking instances of the efficacy of gypsum, and other interesting examples of the same kind are to be found in Mr. J. Chalmers Morton's *Cyclopædia of Agriculture*. The writers, in their own experience, do not find the use of gypsum at all general amongst farmers. As an exception to this, however, there is a considerable quantity used by hop-growers in Kent and Sussex. Several large hop-growers have used gypsum every year, for many years past; and they find that it prevents mould and improves the quality of the hops where it is used.

Anhydrite.—Sussex gypsum is practically free from anhydrite; but small quantities have been found now and then, and it is merely a curiosity at Mountfield. The writers have tried in vain to get specimens for this occasion, but none have been discovered.

Anhydrite is formed artificially, however, in the sludge from the steam-boilers. When using mine-water in the boilers, very little scale is formed, but a precipitation of sulphate of lime takes place; and this is, or becomes, nearly pure anhydrite, in exceedingly fine crystals. It is certain from this, that anhydrite is produced from a solution of gypsum, under conditions existing in a steam-boiler working at a pressure of 60 pounds per square inch; and probably a much lower pressure would produce a similar result. After a series of experiments, Prof. J. H. van't Hoff* con-

* "Gips und Anhydrit," by Messrs. J. H. van't Hoff and F. Weigert, *Sitzungsberichte der Königlich Preussischen Akademie der Wissenschaften zu Berlin*, 1901, page 1140; and Abstract, *Journal of the Chemical Society*, 1902, vol. lxxxii., part ii., page 137.

cluded that anhydrite is precipitated from a saturated solution of sodium chloride containing calcium sulphate at 25° Cent., and thus accounts for the deposition of anhydrite from sea-water in nature.

Mr. T. Trafford Wynne had asked for suggestions for the utilization of anhydrite,* and that must be the excuse for alluding at some length to a matter scarcely affecting Sussex gypsum. It seems not impossible, where anhydrite is found in a state of hardness that does not present insuperable difficulties to its reduction to a fine powder at a reasonable cost, or if by weathering, a sufficient state of softness can be imparted to it, that it might be turned to account by extracting the sulphur from it. The suggested process is remarkably simple, and appears quite feasible commercially, with sulphur at anything like its present price. Anhydrite contains 23·52 per cent. of sulphur, or very nearly one-fourth of its total weight; and 1 ton of sulphur can, therefore, be produced from about 4½ tons of anhydrite. Flowers of sulphur, as a commodity, is quoted, in the prices current given in the *Chemical Trades Journal*, at about £6 per ton; and if the selling price be taken at £5 per ton, or even less, there seems a fair margin for the handling and working of 4½ tons of material. The sulphur from this process would be absolutely free from arsenic and, therefore, of the highest possible value.

The process divides itself into three stages: (1) the reduction of the sulphate of lime to the condition of sulphide; (2) treating the sulphide with carbon dioxide to drive off the sulphur in the form of hydrogen sulphide; and (3) utilizing the gas so driven off for the production of sulphur. The second and third stages of this process have been successfully worked out by the users of the Chance process† for the recovery of sulphur from alkali-waste.

The first part of the process (based upon wellknown chemical principles), as outlined by Mr. F. B. Rawes,‡ is to mix intimately and grind together as finely as possible a proportion of coal or its equivalent of other carbonaceous matter with the anhydrite, and to heat the mixture, out of contact with the atmosphere, in retorts or suitable furnaces. The calcium sulphate becomes reduced to sulphide, and carbon dioxide, or carbon monoxide, or a mixture of these gases would be given off. Theoretically, the calcium

* *Trans. Inst. M. E.*, 1906, vol. xxxii., page 181.

† British patent, 1887, No. 8,666. ‡ British patent, 1882, No. 1,393.

sulphate and coal can be mixed in two different proportions. In each case, the same amount of calcium sulphide is obtained, but the bye-products are different. The first case may be represented as follows:—$CaSO_4 + 2C = CaS + 2CO_2$. That is, 136 parts of anhydrite, mixed with 24 parts of coal or its equivalent, produce 72 parts of calcium sulphide (containing 32 parts of sulphur) and 88 parts of carbon dioxide. The other mixture gives the following reaction:—$CaSO_4 + 4C = CaS + 4CO$. That is, 136 parts of anhydrite, mixed with 48 parts of coal, give 72 parts of calcium sulphide and 112 parts of carbon monoxide. If either of these theoretical reactions could be realized in practice, there would appear to be no difficulty whatever; as, in the one case, the carbon dioxide could be used for the treatment of the calcium sulphide in the second stage of the process; and, in the other, the carbon monoxide might be utilized in heating the retorts or furnaces, or in the gas-engines, etc. In practice, no doubt, a mixture of these bye-products would be produced and an intermediate proportion of coal would be required. There is little doubt, however, that the mixed gases might be profitably utilized with, or without, their previous separation. The calcium sulphide so produced, transferred to a vessel containing water, is treated with carbon dioxide, and hydrogen sulphide is evolved. This gas is mixed with a properly regulated supply of air in a Claus kiln, furnished with a quantity of porous material, where the hydrogen is burned off, and the sulphur sublimed in a condensing-chamber. There would, of course, be a number of sets of retorts or furnaces, and a number of desulphurizing vessels: thus the process would be continuous, the various individual retorts and vessels being successively brought into use. A residue of carbonate of lime would be left from the last operation, in the proportion of about 70 per cent. by weight of the weight of the anhydrite used. This might be utilized in the manufacture of Portland cement, or burned into lime in rotary kilns, or otherwise disposed of.

The advantages and disadvantages, compared with those of the process for the recovery of sulphur from alkali-waste, are as follow:—(1) With the latter, the original alkali-waste costs nothing; whilst with that for the abstraction of sulphur from anhydrite, although the anhydrite itself costs nothing, the process of grinding and heating with coal must be more or less expensive. (2) To compensate in part for this enhanced cost, the writers find that

the calcium sulphide produced is much richer in sulphur than is soda-waste. The latter is said to contain between 20 and 30 per cent. of sulphur, whilst the proportion of sulphur in the reduced anhydrite would be about 44 per cent. (3) Again, in the alkali-waste process, the carbon dioxide must be obtained from a closed lime-kiln; whilst in the anhydrite process, the carbon dioxide would be furnished by the process itself.

Much, of course, would depend upon the effect of such a new supply of sulphur upon the market. At anything like present

FIG. 5.—No. 1 GAS-ENGINE OF 50 NOMINAL HORSEPOWER.

quotations of best sulphur, it does appear as though the process would be successful, if carried out on an adequate scale. It is hardly an undertaking that would be entered into by an individual gypsum-manufacturer, who is not, as a rule, a large capitalist; but if plaster-makers would co-operate with each other for mutual advantages, things might be done which now seem impossible to achieve.

It will be evident that if the treatment proved itself satisfactory in the case of anhydrite, it is only another step to treat gypsum itself in precisely the same manner.

Perkins Engines and Boilers.—When the Sub-Wealden Gypsum Company, Limited, began to get to work, it soon became evident that there were special difficulties to overcome, in the adoption of power of an economical nature. The water, as in the case of most gypsum-undertakings, was extremely hard, whether got from the mine or from the neighbouring stream. The carriage of fuel, from any source, was a costly item; and coal of good quality could not be obtained except at high prices.

FIG. 6.—No. 4 GAS-ENGINE OF 55 NOMINAL HORSEPOWER.

These considerations led to the adoption of Perkins engines and boilers, which were of an exceptionally interesting character.* The boilers were of the water-tube type. Several rings of tubes, superposed one over the other and connected by short vertical tubes, spoken of as "nipples," formed the fire-box. Some of these tubes were not complete rings, but were terminated at the sides of the fire-door, so as to leave an opening in front for firing.

* "A Boiler, Engine and Surface-condenser for very High-pressure Steam, with great Expansion," by Messrs. Alexander W. Williamson and Loftus Perkins, *Proceedings of the Institution of Mechanical Engineers*, 1861, page 94; and "Steam-boilers and Engines for high Pressures," by Mr. Loftus Perkins, *Ibid.*, 1877, page 117.

Above the fire-box, running from front to back, were several sections consisting of straight horizontal tubes, superposed and connected together with nipples in the same way as were the rings. A nipple at each end of the lower tube of the section connected the section with the front and back upper fire-box tube. Superposed upon the whole, and connected to the sections below it with nipples, was a steam-chamber of cylindrical shape running from one side of the boiler to the other. The whole was enclosed in brick-work, and a cast-iron front with fire-doors and man-holes was bolted on. The flues on leaving the boiler were designed to

FIG. 7.—FACE OF LONGWALL GATE-ROAD, SHOWING PACKWALL.

surround a system of water-tubes for heating the water on its way to the boiler. With this boiler and accessories, it was possible to get up steam from cold water in half-an-hour. The pressure, worked at every day, was 450 pounds on the square inch: the pressure being indicated by gauges both at the boiler and at the engine. When working, a vacuum was maintained of about 25 pounds per square inch.

The heat of the steam was so great that lubrication of the cylinders was not possible. It was impossible to use any ordinary water in these boilers and engines, because there must be no deposit inside the water-tubes. The first charge of water was

distilled in an apparatus fixed for that purpose in the water-system. Then the steam leaving the engine was condensed and returned to the distilled-water tank for use again. In this way, very little fresh water was required, and all that was necessary to make up waste, was distilled in the manner described before it went to the engine or the tank. It can be easily understood that no lubricating oil or other matter could be allowed to pollute the water or the steam, if the boiler-tubes were to be preserved.

Both of the vertical engines were triple-expansion and of peculiar construction, with a single-acting high-pressure cylinder at the top and a single-acting medium-pressure one at the bottom,

FIG. 8.—FACE OF LONGWALL GATE-ROAD.

with a common piston-rod actuating one crank; and a double-acting low-pressure cylinder, with a piston-rod actuating a crank at right angles to the other. The steam, on issuing from the high-pressure exhaust-valve, went direct into the lower or medium-pressure cylinder; and then into a chamber which fed the low-pressure cylinder at the top and bottom alternately. All the valves but one were of the tappet type. Anti-friction piston-rings were used; these were subject to considerable wear, and made up the chief item in the repair-bill. The rings of the high-pressure cylinder were usually renewed about every six weeks. The rings of the medium-pressure cylinder would go a few

months, and of the low-pressure cylinder for a year or more. The dimensions of the engines are detailed in Table II.

TABLE II.—DIMENSIONS OF PERKINS HIGH-PRESSURE ENGINES.

Dimensions, etc.		Winding-engine.	Mill-engine.
Diameter of cylinders: high pressure,	inches	5¾	8
,, medium pressure,	,,	10¾	17¼
,, low pressure	,,	15	24
Stroke	,,	15	24
Revolutions	per minute	140	98
Weight of flywheel	tons	6	11

FIG. 9.—WINDING-GEAR, DRIVEN BY TWO BELTS, AND FAST AND LOOSE PULLEYS.

Gas-engines.—The Perkins engines did their work for about 20 years, when it became necessary to consider the question of replacing the boilers. The able inventor had unfortunately died and the manufacture of this kind of boiler had not been continued, whilst other water-tube boilers had not been constructed to stand the conditions of pressure required. It was, therefore, determined that a gas-engine should be adopted as an auxiliary, and as an experiment, at the same time.

The first gas-engine (fig. 5) was erected in the year 1896. It was of 50 nominal horsepower, working to something like 125 indicated horsepower. It was constructed with a loose liner for the cylinder, easily replaced at a small cost, obviating the necessity of renewing the whole cylinder and water-jacket. The engine was guaranteed to work with a consumption of 1 pound of coal per brake-horsepower per hour, and justified the

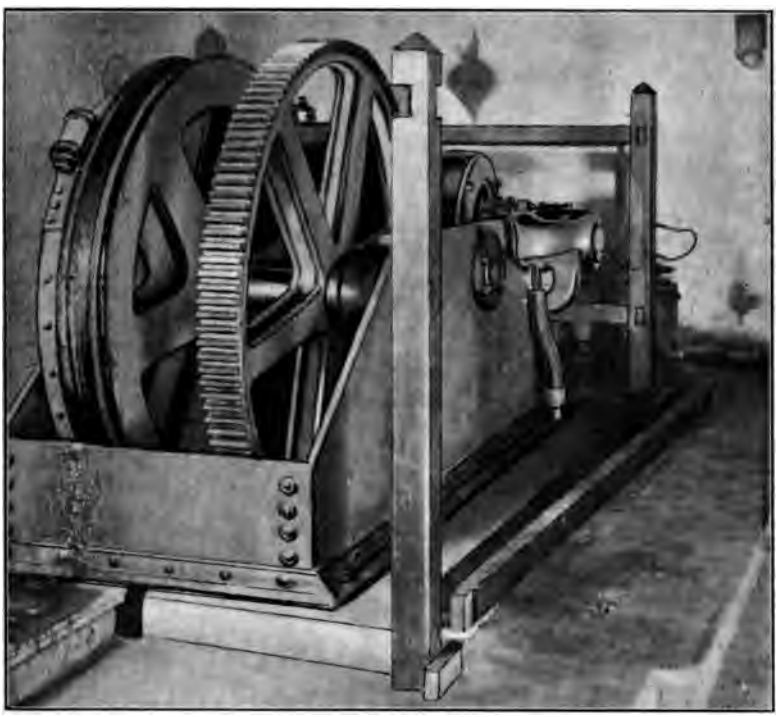

FIG. 10.—ELECTRICALLY-DRIVEN ENDLESS-ROPE HAULAGE-GEAR.

guarantee in actual work. In the year 1899, a second gas-engine of a similar power and type to the first was installed; a third of the same power was acquired in 1901; and in 1904-1905 one of 55 nominal horsepower (fig. 6), and a smaller one for winding purposes. An auxiliary oil-engine is provided to drive the stirring gear of the boiling-pans, which can be driven either by this engine or from the main shafting. Two locomotives are used in turn, to take trucks to and from the works and sidings.

Mines.—The shafts having been sunk, the actual working of the gypsum was commenced in the year 1876: the system of working was originally a kind of pillar-and-stall method, but for various reasons this was found unsatisfactory and costly.

It then appeared to the owners that the conditions of the floor and roof, as well as the thickness of the seam, were fitted to a very large degree for the system of longwall working; and the late Mr. George Lewis, Past-President of this Institution, was called in to advise, and to attempt to carry out this method. The trial was, after some vicissitudes, eminently successful, and the longwall system has since 1879 been prosecuted without intermission. This point, the writers consider, makes the working of this gypsum of particular interest to mining engineers, as it is the only gypsum-mine in the country which has adopted the system. It may be added, however, that other gypsum-deposits, either in the Midlands or in the Carlisle district, do not lend themselves to such methods, and with them a different system is a simple matter of necessity.

There is no need to enter into any description of the manner of working, as the word "longwall" is sufficiently expressive to a technical audience. The roof, however, varies in character: at one side of the mine it is strong, and requires very little timber; whilst on the other side, some 1,200 feet away, the gypsum is overlain by a bed of impure shaly rock which has been honeycombed by wafer until it somewhat resembles a sponge. This bed has necessarily to be taken down; and, although not of a very strong nature, it is used to build the pack-walls.

No attempt, however, is made to work the rock in webs, but the men bore shot-holes where they consider that the shot would have the best effect, and with plenty of gate-roads, they are enabled to get the trams readily to the haulage-rope.

The seam having been worked for some 30 years, it was naturally found about 2 years ago that, without any haulage system at all underground, the labour and cost of bringing the trams from the face to the shaft was becoming excessive. Owing also to the success which has accompanied the undertaking of recent years, a larger output was required, and these facts led to a wholesale re-arrangement of the winding and working

details. Up to that date, the whole of the material had been raised by means of a rope-drum geared to the mill-machinery, raising and lowering a single cage running in a small shaft. The new arrangements provided for the widening of the upcast shaft to a diameter of 11 feet, and the reversal of the air-currents, so that the old winding-shaft became the upcast. A fan was installed, capable of producing as large a current of air as will ever be required at the mine. Previous to this arrangement the ventilation was produced by a fire—hardly large enough to be termed a furnace.

FIG. 11.—WAGON ON ENDLESS-ROPE HAULAGE-ROAD.

At the new shaft, a winding plant has been provided, actuating two cages in the shaft and driven by a gas-engine similar to those producing the mill-power. Two belts, one crossed, transfer the power to the gearing driving the drum, and the moving of one belt or the other from the loose pulleys to the fast pulley provides the motion of the cages in one direction or the other (fig. 9). A neat arrangement, although somewhat difficult to describe, provides for the automatic stopping of the drum in case of an overwind, and also in case of breakage of a rope or other similar mishap.

The gypsum had, until about two years ago, been worked in a longwall face in a north-westerly direction; but it was found desirable to push out in other directions, chiefly north and south. Very curiously, however, the strata were found to dip in both those directions, and a system of power-haulage was deemed necessary. After consideration it was decided that this should be electrically driven, and the following system has been installed. A continuous-current dynamo is driven by belting from the mill-shafting, and the current is taken to an engine-house at the bottom of the shaft, where a motor is fixed driving, through gearing, an endless rope which travels along two north-and-south main roads (fig. 10). This system is, of course, a very small one, and is probably the most diminutive of its kind in the country; but it works exceedingly well, and has been a most useful adjunct to the successful working of the mine (fig. 11).

The mill, pit-bottom, and a portion of the main haulage-roads are lighted by means of lamps connected with the electric cables; and, generally speaking, the mine and its appliances are claimed by the writers to be a model of simplicity, effectiveness, and up-to-dateness.

It may be added finally that a considerable number of men are employed, and the villages of Mountfield and Netherfield have derived great benefit from the discovery of "Gypsum in Sussex."

Mr. G. A. Lewis stated that the specimens displayed on the table showed that gypsum differed widely in appearance, and that there was no dividing-line between the various kinds, ranging from pure white to a dirty-grey colour. A gypsum-mine in the Carlisle district was now being worked, in a very small way, on the longwall system, and not at all comparable with the Sussex mine.

Mr. Isaac Hodges asked how the neutral position was obtained when the cage was standing and the engine running.

Mr. G. A. Lewis replied that the belts were then placed on the loose pulleys. One belt was crossed and the other plain, so that one drove the drum in one direction and the other in the

opposite direction. There were one fixed and two loose pulleys, which allowed of winding being made in either direction or ceasing although the engine was running.

The CHAIRMAN (Mr. W. G. Phillips) asked whether there was any definite parting between the gypsum and the roof.

Mr. G. A. LEWIS said that a practically-continuous thin band of fibrous gypsum divided the stone from the shale at the roof of the mine.

Mr. J. S. MARTIN (H.M. Inspector of Mines) asked Mr. Lewis to give the members some information as to the effect of the weighting of the roof, and as to whether any difficulty had been experienced in this respect owing to subsidences at large breaks and faults. The principle of working at the face was like that followed in rock-salt mines, the mineral being all blasted out. He asked whether the rock, under the bed of gypsum, was suitable for holing.

Mr. G. A. LEWIS said that the mine was only about 150 feet deep, and the country about the mine was simply in the heart of a forest, without roads or buildings. They did not know of any damage to the surface, but such had never been looked for, and he did not think that any difficulty of that sort would ever arise. Of course, the goaf did squeeze and roof had been taken down to make height, but the pillars, left under the old system of working, were substantial and little trouble had arisen from subsidence of roof.

Mr. J. S. MARTIN asked whether the falls spread over a large area, and whether the falls took place on the roads or on the packs.

Mr. G. A. LEWIS said that falls usually took place at the face, when they did occur; but the falls were few, as the packs were built close to the face, and they only covered a small area. It would be practically impossible to "hole" in the underlying strata, or even in the gypsum, owing to the hardness of both. The longwall system had proved successful and satisfactory, and the output was considerable for a gypsum-mine, although, of course, not comparable with a modern colliery.

Mr. Philip Kirkup asked whether the amount of gypsum was small, compared with the amount of material taken out of the mine.

Mr. G. A. Lewis said that nothing was taken out of the mine except gypsum. On one side of the mine especially, a band of rock, taken down from the roof for safety, practically provided packing for that side of the mine; whilst on the other side, a small percentage of useless rock provided most of the packing, which had to be supplemented with gypsum-rock, if found necessary.

Prof. Edward Hull (London) wrote that it was remarkable how, in recent years, the district south of the Thames had been yielding minerals, which were undiscovered and unsuspected up to the middle of the last century: as, for instance, ironstone, not that of the Wealden beds, but much more important and now being worked and smelted at Westbury; then the gypsum-deposit at Netherfield; and last, but by no means least important, the coal-seams of Kent, which in a few years were destined to produce large supplies of mineral fuel for use in the South of England. It was to be for ever regretted that the boring at Netherfield in Sussex, intended to prove, or otherwise, the existence of coal, and carried down to a depth of 1,905 feet, had been abandoned without the desired result, owing to the extraordinary thickness of the Kimeridge clay, and the consequent narrowness of the bore-hole at that depth. A few more feet of depth might have been sufficient to reach Palæozoic strata of some age, and thus have proved a warning or encouragement to further exploration as the result of the experiment. With the knowledge since obtained, it might be doubted whether the site of the boring was well selected; it was probably too far south for coal-strata to have been proved, but it was easy to be wise after the event. Messrs. Kemp and Lewis were doubtless correct in stating that the gypseous deposits now being worked at Netherfield occurred in the Purbeck beds, lying at the base of the Wealden series. This series, as was well known, was of fresh-water, or lacustrine, origin, although at a short distance below the marine beds of the Kimeridge clay occurred. Gypseous beds were common in Cheshire and the Midlands in the New Red Marl, associated with beds of salt, which were also of lacu-

strine formation. It was impossible to suppose that the beds of gypsum could have been formed under marine conditions; and it might be suggested that these beds were originally deposited as limestones, like those occurring at a higher level as shown in the section, but were afterwards converted into gypsum by the influx of sulphurous waters, converting the carbonate into sulphate of lime. If this were so, the gypsum-beds were a secondary product, due to chemical action. The limestones of the Purbeck were full of freshwater fossils such as *Paludina*, *Planorbis;* etc., and they had yielded the well-known Purbeck marble which, in the thirteenth century, was so largely used in ecclesiastical architecture, and of which the slender shafts of Westminster Abbey afforded the most conspicuous example. The directors of the Sub-Wealden Company deserved the greatest credit for the manner in which they had carried out their mining operations, and surmounted the physical and mechanical obstacle which they encountered in opening their mine, and they fully deserved the success which had attended their enterprise.

Mr. David Burns (Carlisle) wrote that, in addition to giving exact details of the occurrence of gypsum in a new locality, this paper was important geologically as throwing one or two rays of light on the origin of such beds. The films of calcareous shale found in the grey gypsum were very direct evidence of the calcareous origin of the mass: the clay of these parts having protected them from the metamorphic influence that attacked the purer rock, and thrust the impurities slightly aside. The lines of satin-spar that occurred at the top and the bottom (as they did in the Eden-valley deposits), and which had never been very satisfactorily explained, seemed to indicate, by their rising and falling, that the bed of gypsum had swelled on its formation into gypsum, and that where purest it had swelled most. This was what must have happened to an irregular bed of calcareous matter attacked by sulphuric acid. Let it be assumed that the calcareous bed was of the nature of calcite, containing 56 per cent. of lime, and of a specific gravity of 2·6. It was attacked by sulphuric acid, the carbonic acid was driven off, sulphuric acid and water taking its place; and every 100 parts by weight of carbonate of lime would become 172 parts by weight of gypsum. Taking gypsum as having a specific gravity of 2·3, the carbonate of lime

that had a bulk of 100 would bulk 194 as gypsum or nearly twice as much. Where the calcareous matter was most compact and pure, this increase of bulk would be greatest, and hence the lines of satin-spar would behave as described. Mr. T. Trafford Wynne had given a drawing* which might indicate something of the same action in the Dove valley; but no instance had come under his (Mr. Burns's) notice in the Eden valley. This difference would be explained by the gypsum-bed of the Eden valley having been a land-surface at the time of the change from carbonate to sulphate, that of the Dove valley having been nearly so, and by the Sussex deposit having been heavily covered when metamorphosed, and probably also from its having been originally a much more irregular bed. If the shales under the Sussex bed were soft and yielding, they would be the more readily indented when the roof was being raised against gravity. The presence of petroleum was significant, and it would be interesting to learn whether the neighbourhood contained many faults, lodes and dykes.

Mr. W. J. Kemp wrote that the 0·2 per cent. of water mentioned by the analyst existed (in the specimens examined) as accidental moisture, in addition to the 20·93 per cent. of water contained and chemically combined in the crystallized gypsum.† The hardness of the grey gypsum was greater than that of the white, but none of the Sussex gypsum approached the hardness of anhydrite.

The Chairman (Mr. W. G. Phillips) moved a vote of thanks to Messrs. Kemp and Lewis for their interesting paper.

Mr. P. Kirkup seconded the resolution, which was cordially approved.

Mr. Herbert F. Broadhurst read the following paper on "Water-supplies by means of Artesian Bored Tube-wells":—

* *Trans. Inst. M. E.*, 1906, vol. xxxii., page 184, plate x., fig. 3.

† *Ibid.*, 1907, vol. xxxiii., page 451.

WATER-SUPPLIES BY MEANS OF ARTESIAN BORED TUBE-WELLS.

By HERBERT F. BROADHURST (in connection with Messrs. C. Isler & Co., London).

Introduction.—The question of both public and private water-supplies is continually increasing in importance. Water companies and local authorities operating water-supplies are constantly finding it necessary to tap fresh sources of supply, so as to meet the growing demands and at the same time to provide a water of a higher standard of purity.

Numbers of small towns, previously dependent on private wells only, have been obliged to face the question of a public supply of pure water to replace these wells. In many cases this has been found necessary, owing to the widespread pollution of the surface-waters from which small private wells obtained their supplies: such pollution affecting all the wells in the entire district. The same thing occurs on large private estates, where it is frequently found that old surface-wells have failed to yield the required supply or have become polluted, making it necessary for fresh supplies to be obtained or a central water-supply system to be put down for the whole estate.

Another reason for the continually increasing demand for private water-supplies is the cost of buying water, when required in large quantities. Large works and factories of all kinds, and public institutions, such as baths, workhouses and hospitals, find that a large saving can be effected by putting down wells and pumping their own water-supply instead of buying water from the mains. Hotels and large blocks of business-premises are now putting down private wells and pumps. The saving effected is surprising. In many cases the total cost of the bore-hole and of the pumping-plant has been saved in less than two years, showing a return of over 50 per cent. per annum on the capital expended, after allowing for working costs, repairs and depreciation.

In the case of large works, using from 10,000 to 20,000 gallons per hour, or, say, 150,000 gallons per day, the usual cost of the

water supplied by meter would be about 6d. per 1,000 gallons, whereas, with bore-holes and modern pumping-plant, the supply could be pumped for a total cost of about 1d. per 1,000 gallons, showing a clear saving in cost of water of about £2 10s. per day or, say, about £750 per annum.

In the case of large business-buildings, hotels and warehouses, the saving can be equally great, even if only a comparatively small supply is required. Owing to these being domestic supplies, the water-rate is charged on the rateable value of the building, making the cost of the water out of all proportion to the amount supplied. In such cases, deep bore-holes and small electrically-driven pumping-plants are adopted, ensuring an ample supply of pure water at a cost averaging about 1½d. to 2d. per 1,000 gallons and showing a large saving per annum: the amount depending on the water-rate that would be charged to the building. Frequently a duplicate pumping-plant is installed, and no connection is made to the mains.

For breweries, a private supply is indispensable, in order to be able to obtain sufficiently cold water for refrigerating and temperating. In most cases, the main-water, in addition to being very costly to use for this work, is too warm in summer-time to be available; whereas well-water can be depended on for a uniform temperature, averaging between 51° and 53° Fahr., all over the country.

Public baths, owning private supplies, are actually able to pump the whole of the water which they require at no cost for power through the use of steam-driven condensing pumps. The steam is employed first to drive the pump, and afterwards to heat the water up to the necessary temperature for the swimming baths, the water is usually pumped at 52° and heated to 74° Fahr. Where no pumps are in use, the heating is now generally done with live steam, and practically the same amount of steam is required to heat the water only, as to first pump up and then heat it, nearly the whole of the heat in the steam going into the water after the steam has been expanded in the cylinders of the pumps. In winter-time, when the water from the mains comes in very cold, it is often found to be actually cheaper to pump and heat the well-water than to heat the very cold water from the mains to the necessary degree. Of course, these advantages are lost in the case of electrically or gas-driven pumps: so that for

baths, or in any case where the water is required to be heated, steam-driven pumps should be employed.

Sunk Wells.—Most of the older wells were what is known as sunk or dug wells, lined with brickwork or cast-iron cylinders, or were sunk as far as the water-level and bored the remainder of the distance. This sinking for a part or the whole of the depth was a source of trouble and expense, and is not now necessary. There was, moreover, always the risk of polluted surface-water percolating through the brickwork or going down behind the cylinders and contaminating the lower pure supplies. In the case of the partly sunk and partly bored well, the remedy is to extend the lining tubes of the bore-hole to the surface, make the bottom of the dug well water-tight with a considerable thickness of concrete, and then fill up the dug well: leaving the water-tight steel-lined bore-hole only, and pumping from it with either a bore-hole pump or by the new air-lift system. In other cases of contamination by surface-water, a fresh boring can be put down from the bottom of the dug well and then the well is filled up; or the well can be filled up, and a bore-hole put down on another site.

The expense, again, of sinking a dug well, after the water-level is reached, is very heavy and is very much against this system, owing to its being necessary to pump out the whole available supply of water while the sinking is going on.

Artesian Bored Tube-wells.—These difficulties are all overcome by the artesian bored tube-well. By this system, a boring is carried entirely from the surface and lined with water-tight steel tubes, which can be forcibly driven downward, so as to seal them tightly into the ground, for the whole of their length and thus prevent any possible leakage of surface-water or undesirable springs into the bore-hole. Also by this method, the bore-hole can be carried deep into water-bearing strata, forming a natural reservoir. There is consequently no necessity to sink a shaft and drive headings for storage; and the bore-hole can be lined at any part, perforated pipes being put in where required and solid tubes driven or sealed into the ground by means of cement, so as to shut out any undesirable sources of supply.

Modern artesian wells are bored and finished with a single

tier of lining tubes of the same diameter from top to bottom, without telescoping of the tubes or reductions in the diameter of the bore. To carry out work in this way, heavy boring plant, sound lining tubes, and considerable experience are necessary; and without these essentials a bore-hole cannot be completed in a proper manner. The old-fashioned plan of drilling and lining consisted in inserting a number of different sized tubes, telescoped inside each other; and, when one tier of tubes became set in the ground and could not be got down any further, another set of tubes were put down inside them and the boring continued. Sealing the tubes in the ground was not in any way considered, and could not practically be executed. In consequence, there was frequent failure of the work, either at once or after a few years, either through sand silting in, or through surface or other polluted springs percolating into the bore-hole and contaminating the supply.

The success of a modern artesian bored tube-well is largely due to the well-lining tubes employed. Often in the case of defective bore-holes, which let in sand with the water or undesirable springs, the cause can be traced to the use of inferior tubes. The lining tube should really be the first consideration, as employing a cheap-made tube makes it almost impossible to line the bore-hole in a proper manner, chiefly because they will not stand the heavy driving required to force them into the ground to make a tight joint and shut out the upper springs. It is also frequently necessary to raise the tubes with powerful hydraulic jacks to free them, or partly withdraw them to undercut so as to get them down; and, unless a really first-class well-made tube is employed, the result is likely to be either a useless or an unsatisfactory well. For the same reasons, tubes known as flush-jointed, that is, one tube screwed into the other without any sockets, are useless for lining artesian bored tube-wells.

To put down a finished boring of the same diameter from top to bottom and to line it successfully, it is necessary to commence with a larger size of lining tube to hold up the upper part of the bore-hole, while proceeding with the boring and the lining of the lower part. In some cases, it is necessary to employ two or three tiers of preliminary guide-tubes, each deeper than the last, before putting in the final lining tube, the number depending on the depth to which the bore-hole has to be lined and the nature of

the ground. On the completion of the bore-hole, these outer tubes are withdrawn and the space can be filled with clay or cement.

In the case of the water-bearing strata, overlain by porous beds such as the alluvial gravels to be found at the bottom of most valleys and many other places, it is most desirable that one of these outer lining tubes should be driven into the impermeable stratum underlying these beds, so as to shut out the water from them, as this water is generally contaminated through want of, or through a defective drainage-system, and in any case it is always liable to become contaminated. Then, on the completion of the bore-hole, the tier of tubes shutting out this surface-water should be retained, and the space between them and the bore-tube proper should be grouted with cement. This not only effectively seals out the surface-water, but it protects the bore-tube against corrosion.

When a water-bearing stratum crops out and is of the same nature from the surface to the level at which the water is tapped, the same steps with regard to the lining of the well should generally be taken, with this difference, that the inner-lining tube should be carried, say, 20 to 30 feet below water-level. This method also applies to cases where the water is contaminated through percolation finding its way from existing dug wells, cesspools or defective drainage; but each individual case requires to be dealt with according to the district and to its geological position.

For a permanent and continuous supply, it is generally advisable to carry the bore-hole between 100 and 200 feet below the point where the water is first reached. There are, of course, exceptions when an abundant supply has been found as soon as the water-bearing bed is reached, and proceeding with the boring every foot deeper increases considerably the volume of water.

The quantity of water obtained depends entirely on the geological formation of the water-bearing strata, for in some the channels or fissures are larger, and consequently the percolation becomes freer, and the flow is therefore more rapid. Copious supplies are found in the following strata, namely:—The Woolwich and Reading Beds overlying the Chalk, Upper Greensand, Lower Greensand, Oolitic beds, Red Marls, New Red Sandstone, Bunter Conglomerate or Pebble-beds, Magnesian Limestone, and

from rocks in the Coal-measures, but from the underlying shales the results are doubtful.

In some instances the process of well-boring may appear tedious, but in any case it is much more expeditious and reliable than sinking shafts. It becomes tedious when deep layers of clays, and dead and blowing sands are overlying the water-bearing seam, and necessitate the lining of the hole as each foot is drilled; also when different springs are struck and each requires to be eliminated owing to its objectionable character. When doubts exist as to the purity of the water, each spring tapped should be tested by pumping, and samples obtained for analysis; and, if found unfit for the purposes required, they can be excluded safely by driving the lining tube below the level of these springs.

Cement-seals.—Frequently the sealing-off can be very effectively accomplished by the use of a special process, by which cement is forced into a recess behind the bottom of the pipes, effectually filling the whole space round the pipes and the surrounding fissures if such exist. In the case of an old bore-hole or of a bore-hole already completed, with the lining tubes fixed in position, this sealing-off can still be accomplished by relining the bore with another tube carried down to the required distance and the recess with the cement forced into it fixed at the bottom of this tube.

Recently, a successful cement-seal was fixed for the London and North-western Railway Company, at Monument Lane, Birmingham (fig. 1, plate xviii.). The bore-hole was lined with tubes, *ab*, 15½ inches in diameter, to a depth of 152 feet below the surface. The running water-level, *c*, is at a depth of 136 feet. An ample water-supply was obtained from the Red Sandstone; but it was found to be too hard for the use of locomotives, so it was decided to try if a softer water was obtainable from the lower part of the bore-hole. This was therefore tested with a temporary expanding plug made of indiarubber, put down the bore-hole on a smaller tube, with arrangements for expanding the plug tightly into the bore-hole at any point. This plug was tried in different positions, and samples were taken each time of the water in the bore-hole below the plug. It was found that below a certain point the required soft water could be obtained. The temporary plug was then removed, and a new lining tube, *de*, 13½ inches in in-

ternal diameter, put down to a depth of 330 feet below the surface. A recess was cut, and the cement-seal, *fg*, was made outside the lower end of these tubes (fig. 1, plate xviii.). The space outside of the tube, *de*, was filled with cement. The supply was not in any way diminished, and the hardness of the water was only 4 degrees instead of 16 degrees as previously. The air-pipe, *hi*, 2½ inches in diameter, from the air-compressor, and the water delivery-pipe, *kl*, 5 inches in diameter, are attached to the foot-piece, *j*, at a depth of 270 feet.

The same process was also used at the Mellin's Food factory and at the West Ham Corporation works, both near London, to shut out sand-water containing iron, and in each case it was perfectly successful.

Another kind of plug was used at a brewery at Leeds. Two bore-holes, yielding water strongly impregnated with sulphuretted hydrogen, were tested; and it was found that the objectionable springs were situated at the bottom of the bore-holes. In this case, the plug was fixed in each bore some distance above the bottom, completely excluding the lower waters and a new bore-hole was put down to the same depth at which the old ones were plugged up. The result is that all the wells are now yielding a wholesome and suitable brewing water.

Diameters of Tube-wells.—The diameters of artesian bored tube-wells vary from 3 or 4 inches in internal diameter, the smallest sizes bored, up to 20 inches in internal diameter, and there are the usual intermediate sizes between these; but borings are made and lined with steel tubes up to 36 inches in internal diameter. A well, bored at Dartford, was lined with cast-iron cylinders 6 feet in internal diameter, with a bore 24 inches in diameter, from the bottom, from which a supply of 60,000 gallons per hour was obtained. The bore-hole, 6 feet in diameter, was put down, and the cylinders fixed with the water-level standing close to the surface, no pumping being employed.

Another well, at Chatham, was bored through the Chalk and Gault and into the Lower Greensand, and lined with a single tier of tubes, 18 inches in internal diameter and 700 feet long. This size of tube reached the Greensand; and a short length of perforated tubes was lowered through them into the Lower Greensand.

From many wells, 10 and 12 inches in diameter, supplies of 12,000 to 30,000 gallons per hour are being obtained, and in some cases considerably more.

Driven Tube-wells.—For small supplies, in cases where a sufficiently good surface-water is obtainable, or where the quality of the water is of no importance, supplies can be obtained cheaply by means of the driven tube-well. This is simply a pointed tube, generally about 2 or 3 inches in internal diameter, having the last few feet perforated with holes. This tube is driven into the ground by a falling weight, to such a depth that the perforated part of the tube remains in coarse gravel, or some such formation, through which the water can flow freely. A pump is attached to the top of the tube, and the water is drawn by suction. Supplies of from 500 to sometimes considerably over 1,000 gallons per hour can be obtained from a tube, 2 inches in diameter. This method, however, is not available for a depth of more than 30 to 40 feet below the surface, and for anything deeper a well must be bored.

Methods of Boring.—The most common method of boring in this country is the percussion-system used with iron rods. These rods are screwed together in lengths of 10 to 15 feet, so as to reach to the bottom of the bore-hole. The cutting is done by a hardened steel chisel, of the same width as the diameter of the bore-hole and from 1 inch to 2 inches thick. The method employed is by lifting and dropping the rods, known as punching, the rods being raised by tightening the turns of a rope or chain round the revolving drum of a winch and dropped by slackening off the turns, and at the same time rotating the rods slowly by hand so that the flat chisel cuts all over the bottom of the bore-hole, crushing the soils and mixing them with the water into a slurry. After cutting a few feet in this manner, the rods and chisel are withdrawn, and the slurry is removed by a shell-tube or sludge-pump, put down either on the rods or run down the bore-hole on a wire-rope. The lining tubes are fitted with a steel cutting-shoe and follow down, or are driven down as the hole is bored. Frequently it is necessary in hard material to undercut, that is, to enlarge the bore beneath the tubes with an expanding chisel. A large variety of other tools are also employed, for trimming the hole and recovering broken rods and tools.

Another method of boring is by using wooden poles instead of iron rods. In this case the weight is put on the chisel by several heavy iron bars fixed immediately above it, known as "sinker-bars." The wooden rods are worked up and down in the bore-hole by a punching beam, driven from a crank, and a sharp blow is obtained by the use of jars or loose links placed between the rods and the sinker-bars. This arrangement enables the chisel to strike the bottom while the crank is in the centre of its stroke and moving at its greatest velocity. The remainder of the movement of the crank and of the rods is taken up in the jars. In this method, the rods are removed in the usual way, and the shell-tube is run down with a wire-rope to remove the slurry.

Another method is practically the same, but involves using rope instead of wooden rods. In this case, a punching beam is employed; and, in the bottom, a chisel, sinker-bars and jars.

Another method is also by percussion, employing hollow rods instead of solid ones, and forcing water through them by means of steam or other power. As the rods are lifted up and down, the chisel strikes the soil through which it is cutting, the water, forced through the hollow rods, issues at the extremity of the chisel through holes drilled for the purpose and washes all the débris to the surface, so that the drilling is done in one operation instead of several, as in the other systems. Whenever this principle can be used, it will be found most expeditious and economical. On an average, it requires from 200 to 700 gallons per hour, and more in the case of a large bore-hole; but means can be taken to use the water over and over again, thereby lessening the consumption.

Diamond drilling is executed by rotating the rods and forcing water through them, to keep the diamond-crown lubricated and to wash the slurry out so as to prevent the tool from becoming wedged or set. The core thereby travels upwards inside the crown-tube, as the tube descends. The crown and the crown-tube are made in lengths according to the soil which is being perforated, and varying from 10 feet to 50 feet, or more if necessary. This process is only required in solid rock formations, otherwise the above-described systems are quicker, more reliable, and less expensive to work.

The diamond rock-drilling process is now almost entirely superseded by the shot drill which works on somewhat the same

principle; but expensive diamonds, requiring so much care and delicate handling in setting and using, are not used. Large and deep bore-holes are now drilled by this process.

Fig. 2 shows a general view of a shot-drilling plant in use at Malvern, where a bore-hole was put down to a depth of 900 feet; the cores taken from this hole are shown piled up against the side of the shed. Fig. 3 is a detailed view of the drilling gear. On the left is the steam-winch used for handling the tools, rods and lining tubes. In the centre is the boring gear used for rotating the rods, with the swivel-head above it which suspends

FIG. 2. SHOT-DRILLING PLANT, MALVERN.

and takes the weight of the rods while drilling; the flexible connection for the water-supply; and the cup-arrangements for feeding the shot into the rods. On the right-hand is the counterbalancing gear, with the handwheel by which the man in charge can raise and lower the whole weight of the rods and regulate the feed while running. In front of this is a steam-pump, supplying water under pressure to the hollow rods.

The system is simply a hollow crown at the bottom of the hole, almost the same as for diamond drilling; but, instead of being set with diamonds to cut the rock, hard steel shot are run

loose underneath the crown; and, with the pressure of the crown above them, these shots roll a path in the stone which is crushed and ground away. The slurry thus formed is washed up by the water pumped under pressure downward inside the rods and tools. As the tools cut away the stone round the edge of the bore a solid core is left, and the core-tube above the cutting crown slides down over this core. When the core-tube is full, the tools are lifted and a wedging action takes place at the bottom of the core-tube, which grips the core and breaks it off; and then the core is brought to the surface in the core-tube. By this

FIG. 3.—SHOT-DRILLING PLANT, MALVERN.

method, fissured rocks and conglomeratic strata can be drilled easily; while it would be almost impossible to drill them with diamonds, owing to difficulties arising from the stones wedging and breaking.

Testing Bored Tube-wells.—On completion, the tube-well should be tested by means of pumping. The action of the pump not only helps to increase the yield, but also to clear the fissures or crevices of the rocks, which have naturally become partly clogged through the continuous working of the tools during boring opera-

tions, and it is found in practice that pumping a bore-hole increases the supply. Should there be an insufficiency of water at the outset, the pumping should not be discontinued too hurriedly, but should be persevered with for some time longer, as an improvement will frequently show itself.

Should the pumping, however, fail, it should not always be taken for granted that failure will be the result, as other artificial means can be taken to create a freer waterway, that is, to torpedo or fire some powerful explosive, such as gelatine, one of the strongest agents for this purpose. Fig. 4 shows a shot being fired in a bore-hole in South Wales. This method is not commonly practised, but it is highly recommendable when the rocks of the water-bearing strata are closely jointed. The explosive is used to shatter and open fissures or crevices of the rocks for the purpose of increasing the flow of water.

FIG. 4.—FIRING A SHOT IN A BORE-HOLE, SOUTH WALES.

In many cases the results are marvellous, the supply increasing beyond all expectation. At Messrs. Peters' cement-works, near Rochester, a single gelatine cartridge weighing 18 pounds was exploded at a depth of 307 feet from the surface, in the Lower Greensand formation, composed of rocks and compact sands. A

water-supply of 20,000 gallons per hour is now obtained, where no supply existed previously. This tube-well, 15 inches in diameter, is lined to a depth of 298 feet.

In cases of apparent failures, where blasting would not obtain the required result, such as obtaining supplies from sand-beds, the air-lift pump has, of late years, provided another very valuable means of developing supplies. An instance occurred at Willesden, where there is practically no water in the Chalk. On the completion of the boring, the supply proved to be less than 1,000 gallons per hour. Air-lift pumping was therefore resorted to, and the sand-beds were forced by a system of applying air-pressure to the bore-hole at regular intervals, meanwhile pumping continuously by an air-lift. By these devices, the supply was gradually increased; and although, at first, large quantities of sand were drawn into the tube, it was all pumped out with the air-lift, many tons of sand being removed in this manner. As the supply came in more freely, less sand was raised, and the water gradually became clear. The final result was a continuous supply of 10,000 gallons per hour of excellent water, quite clear, and free from sand.

FIG. 5.—ARTESIAN TUBE-WELL, BOURNE STATION, LINCOLNSHIRE.

At Bembridge, Isle of Wight, a bore-hole had not been pumped for some time; and, when the permanent air-lift pump was fixed, it was found to be filled with blue silt and the whole of the water-supply was shut out. In this case, the air-pressure system was used, with the result that the water broke in, washing up the silt with it, and it was all pumped out by the air-lift. The original water-supply of 6,000 gallons per hour was restored, and in a few hours the supply was pumped clear: the whole operation being completed in one day. In many cases this system has been successfully employed to obtain water and increase the supply, where it would not have been possible with ordinary pumps.

FIG. 6.—ARTESIAN TUBE-WELL, WEST DRAYTON, LONDON.

Artesian Tube-wells.—In a few cases, the water-supply will naturally overflow from the bore-hole. Fig. 5 shows a very large overflow obtained from a boring, 11½ inches in diameter, and sunk in the White Limestone for the Great Northern Railway Company at Bourne station, Lincolnshire. Fig. 6 shows an overflow from a bore-hole for the Rotary Photo Company, at West Drayton, close to London. In this case, the water overflowed at

the rate of 1,000 gallons per hour to a height of 14 feet above the surface; and, when tested with a surface pump, 12,000 gallons per hour were obtained.

Fig. 7 shows an air-lift plant testing the well at the Hackney baths, London, where 10,000 gallons per hour were obtained from a bore-hole 11½ inches in diameter. The delivery-bend was taken off the top of the air-lift pipes, and the illustration shows the first rush of water straight up the delivery-pipe in the bore-hole on starting the air-lift. Fig. 8 shows a bore-hole, 7¼ inches in diameter, at the works of Messrs. Vickers, Sons & Maxim, Limited, Erith, being tested by a pulsometer at the rate of 15,000 gallons per hour. Fig. 9 shows the water-supply from a bore-hole at Messrs. White's works, Birmingham, being measured by a weir-box: the water is being pumped by an air-lift, and the supply is gauged by the depth of the flow of water from the notch at the end of the box. Fig. 10 shows test-pumping with an air-lift, at the Kent water-works, at Dartford: the compressor can be seen on the left-hand; the well is in the centre, under the derrick; and the water can clearly be seen coming from the end of the delivery-pipe.

FIG. 7.—AIR-LIFT PUMP TESTING A TUBE-WELL, HACKNEY, LONDON.

Pumping-plant.—When considering the question of permanent pumping-plant for an artesian bored tube-well or for a dug well, it is always a desirable precaution and generally necessary to have a test made with a temporary plant, so as to ascertain the quantity of water available and the level to which the water falls when pumping, in order that the proper length and capacity of pumps can be inserted at once, unless these particulars are already available. The saving on the cost of the permanent pumps, through knowing the exact particulars, will always pay for the cost of a test.

FIG. 8.—PULSOMETER TESTING A TUBE-WELL, ERITH, LONDON.

When the supply is ascertained by testing, the style and capacity of the permanent pumps can be decided upon. If it is an overflowing bore-hole, or one from which a sufficient supply can be obtained within 30 feet of the surface, of course, ordinary surface pumps of any type can be used; but, if the pumping level is below this, it is necessary to pump the bore-hole, either by a bore-hole pump or by an air-lift pump. A bore-hole pump consists of a series of tubes connected together in the same way as the well-lining tubes, lowered into the bore-hole and suspended from the surface by flanges secured to the top of the bore-pipe;

FIG. 9.—WATER-SUPPLY FROM A TUBE-WELL MEASURED BY A WEIR-BOX, BIRMINGHAM.

FIG. 10.—AIR-LIFT PUMP TESTING A TUBE-WELL, DARTFORD.

and the pump-barrel and the suction-pipe are secured to the end of this tube. The pump-rods are passed down the centre of these tubes, and are connected to the bucket; and at the surface they are passed through a packing gland. The rods work in the water inside the rising main. By withdrawing the rods, both the pump-bucket and the foot-valve can be removed for repairs, without disturbing the main or barrel. This kind of pump is worked by a crank and a connecting rod, or it can be built as a direct-acting steam-pump, with an inverted steam-cylinder directly connected to the top of the rods. This arrangement makes a quiet-working pump, occupying little space; but it is not

FIG. 11.—DEEP-WELL PUMP, HATFIELD.

economical, as it cannot be worked expansively and the full pressure of the steam must be carried to the top of the stroke, where it is released and discharged into the atmosphere. A deep-well pump, worked with a crank and gearing and driven by a good engine, is, on the contrary, a very economical machine, and requires less power than any other method of pumping bore-holes.

Fig. 11 shows a gear of this type, supplied to the Marquis of Salisbury, for Hatfield water-works. This set when tested, although a comparatively small pump raising 8,000 gallons per hour, gave an efficiency of 75 per cent. of the indicated horse-

FIG. 12.—DEEP-WELL PUMP, WORCESTER.

FIG. 13.—DEEP-WELL PUMP.

power. Fig. 12 shows the gear of a larger pump raising 25,000 gallons per hour for the East Worcester water-works. Fig. 13 shows another gear of the same size built for Messrs. Barclay, Perkins & Company, when erected in the works ready for fixing. This pump, 20 inches in diameter, is fitted with an extra crank, carrying counterbalance-weights to equalize the work on the up and down strokes, and a plunger-pump at the surface, half the area of the bucket: this pump displaces half the supply at every down stroke, thus making the pump double-acting above the surface.

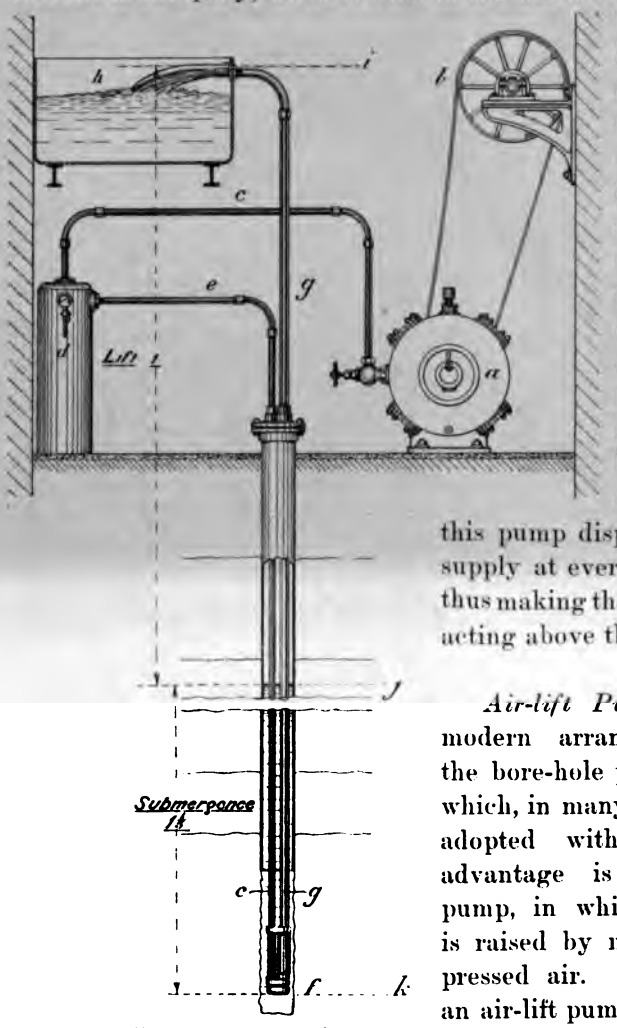

FIG. 14.—ELEVATION OF AN AIR-LIFT PUMP IN A BORE-HOLE.

Air-lift Pump.—A more modern arrangement than the bore-hole pump and one which, in many cases, can be adopted with considerable advantage is the air-lift pump, in which the water is raised by means of compressed air. Fig. 14 shows an air-lift pump applied in a bore-hole. The air, supplied from a circular four-cylindered air-compressor, *a*, driven by a belt and pulley, *b*, passes through the pipe, *c*, to the combined air-receiver and oil-extractor, *d*, and from this down the air-pipe, *e*, in the bore-hole to the foot-piece, *f*, where the air mixes with the water. The

mixed air and water are delivered from the larger pipe, *g*, to the surface-tank, *h*, where the air instantly separates from the water.

This system possesses the following advantages: there are no working parts in the bore-hole; nothing but straight open-ended pipes, with nothing to go wrong or require repairing; all the machinery is accessible at the surface, and need not be placed near the well; thus the bore-hole can be fixed near the water-tank and the air-compressor placed in the engine-room some distance away. Another important point is that, owing to the small size of the pipes required, about three times as much water can be raised from a certain sized bore-hole as with a deep-well pump, that is, of course, if the water-supply exists.

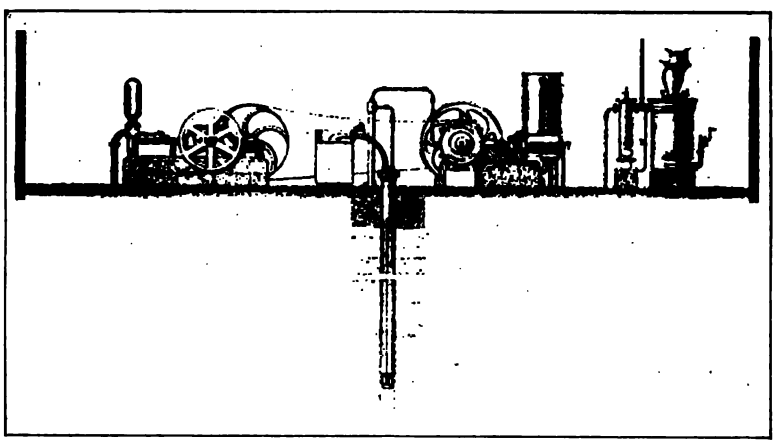

FIG. 15.—AIR-LIFT PUMP AND SURFACE PUMP DRIVEN BY A GAS-ENGINE.

Thus the air-lift pump saves capital cost, as a much smaller bore can always be put down, and frequently, in the case of large water-supplies, the whole can be obtained from one bore-hole instead of having to put down two bore-holes. It is also possible by this system to duplicate the pumping-plant on a single bore-hole; and, of course, with deep-well pumps duplication is impossible. The limitations of the system are as follows: it cannot be used to pump a hole empty; there must be sufficient depth of water to submerge the pipes, and this submergence must, for economical working, be rather greater than the total lift; thus, if the total lift, *ij*, is 100 feet, the minimum working depth of water, *jk*,

FIG. 18.—GAS-ENGINE DRIVING A FOUR-CYLINDERED AIR-COMPRESSOR, BURNHAM.

FIG. 19.—GAS-ENGINE DRIVING A FOUR-CYLINDERED AIR-COMPRESSOR, BURNHAM.

four cylindered air-compressor. The surface pump at Burnham water-works, drawing from a large glazed-brick surface-tank, into which the air-lift pump delivers, forces the supply into the mains. This plant was started and was put to work, pumping the full water-supply on the same day. It has not been out of service and has given no cause for anxiety since, and is a good example of pumping with an air-lift and suction-gas. The water-supply delivered is 12,000 gallons per hour, and the total head, from the pumping level in the bore-hole to the reservoir-of 300 feet, is divided into two lifts. The air-compressor raises the water, 120 feet, from the pumping level into the surface-tank; and the three-throw belt-driven surface pump draws from this tank and delivers to the reservoir against a head of 180 feet. This plant, when running, uses 20 pounds of anthracite-coal per hour, at a cost for fuel of ¼d. per 1,000 gallons; and over six months the average cost of fuel was less than ½d. per 1,000 gallons delivered to the reservoir.

Mr. G. A. Lewis (Derby) asked whether any difficulty had been experienced in breaking off the cores with a shot-drilling plant.

Mr. H. F. Broadhurst said that there was no difficulty; the tail-piece gripped the cores and brought them out, but more generally the core was broken. A core, 10 feet long, was often broken in two or three places.

Mr. Frank Coulson (Durham) said that Mr. Broadhurst stated that "public baths . . . . are actually able to pump the whole of the water they require at no cost for power . . . . nearly the whole of the heat in the steam going into the water after the steam had been expanded in the cylinders"; * and it would be interesting to know the quantity covered by the word "nearly," which would be the cost of pumping. It was further stated that "modern artesian wells are bored and finished with a single tier of lining tubes . . . without . . . reductions in the diameter of the bore." † "To put down a finished boring of the same diameter from top to bottom . . . . it is necessary

* *Trans. Inst. M. E.*, 1907, vol. xxxiii., page 474. † *Ibid.*, pages 475-476.

should be 120 feet. The air-lift pump has the disadvantage that it cannot be used to pump horizontally, and the delivery-pipe must rise to the required height and then turn over into the tank with a long easy bend. If the water is required some distance away, it should be pumped to the required height, and delivered into a tank, in which the air and water separate, and then allowed to flow by gravitation to the point required.

Fig. 15 shows an air-lift pump for a small water-works driven by a gas-engine and suction gas, the gas required to drive the gas-engine being generated as it is required. The compressor

FIG. 16.—STRAIGHT-LINE AIR-COMPRESSOR, BATTLE.

is built on the crank-shaft of the gas-engine. The water is delivered by the air-lift into the surface-tank, where it is picked up by the surface pumps, shown at the left-hand side, and delivered into the mains and forced to the reservoir. The combined air-lift and surface-pump plants in this manner will raise a supply to a height of 300 feet, for a fuel-cost as low as ¼d. per 1,000 gallons, and can be worked constantly with a minimum of attention. The whole plant is as reliable as steam-driven machinery.

A steam-driven air-lift pump and surface-tank fixed at the public baths in Prince of Wales road, London, raises 15,000 gal-

lons per hour: being one of two similar sets fixed. A condenser is fixed over the surface pump, and the supply from the surface-tank is pumped through the condenser on its way to the baths, thus heating the water to the required temperature at the same time as it is pumped. The same quantity of steam would be required to heat the water, even if it were taken from the mains, so that actually the pumping costs nothing: the whole of the steam being utilized for heating the water.

Fig. 16 shows a straight-line air-compressor, doing good duty at Battle water-works, and raising a water-supply of 8,000 gallons per hour.

Fig. 17 shows a double-ended, multi-cylindered air-compressor at the works of Messrs. Elliott's Metal Company, Birmingham. The delivery of water through the air-lift is shown, together with the long-delivery bend and splayed cast-iron delivery-nozzle, affording an easy outlet for the water. The water-supply is 10,000 gallons per hour and from a depth of 230 feet.

FIG. 17.—DOUBLE-ENDED FOUR-CYLINDERED AIR-COMPRESSOR, BIRMINGHAM.

Fig. 18 shows a combined gas-engine for suction gas, and a new pattern of air-compressor, fixed at Burnham water-works. Fig. 19 shows the same engine and the compressor with the door removed, showing the crank and connecting rods of the

FIG. 18.—GAS-ENGINE DRIVING A FOUR-CYLINDERED AIR-COMPRESSOR, BURNHAM.

FIG. 19.—GAS-ENGINE DRIVING A FOUR-CYLINDERED AIR-COMPRESSOR, BURNHAM.

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* *Trans. Inst. M. E.*, 1907, vol. xxxiii., page 474. † *Ibid.*, pages 475-476.

to commence with a larger size of lining tube. . . . In some cases, it is necessary to employ two or three tiers."* He asked which of these statements was correct, and for his own part he thought the last. It would be of interest to know from what depth and how 30,000 gallons of water per hour could be obtained from bore-holes 12 inches in diameter, or how 1,000 gallons of water per hour could be pumped from a tube 2 inches in diameter. A number of methods of boring were named, and it was stated that by shot-drilling fissured rocks could be drilled easily. Would not the shot leave the bore-hole and find its way even into small fissures and be useless? In describing the air-lift pump, no mention was made of the percentage of efficiency obtained from the various depths from which the water was raised. In the case of the supply of 10,000 gallons of water per hour from a depth of 230 feet, at the works of Messrs. Elliotts Metal Company, Birmingham, did this mean that the bore-hole was something over 470 feet deep? He (Mr. Coulson) believed that the air-lift pump, although very efficient for testing the supply of water from a bore-hole, was an extravagant method when the water had to be lifted from anything over a depth of 70 feet. Would Mr. Broadhurst give the members the result of his experience as to the decrease of efficiency as the depth from which the water was to lift increased, say for each 50 feet; and did not the efficiency decrease very rapidly in proportion to the depth?

Mr. G. Elmsley Coke (Nottingham) wrote that Mr. Broadhurst, in the introduction to his paper, apparently assumed that there was a plentiful supply of good water in the ground. It was hardly necessary to say that these conditions were exceptional. In the city of Nottingham, which was partly situated on the Bunter Sandstone, there was great variation in the quantity and quality of water derived from wells not far apart. In most cases, before expensive works were commenced, it was necessary to ascertain the quality and quantity of underground water by boring. A difficulty was usually found afterwards in excluding surface-water from the bore-hole, and if the artesian system could succeed in doing this, no doubt there would be many cases where it might be usefully employed.

* *Trans. Inst. M. E.*, 1907, vol. xxxiii., page 476.

Mr. H. F. Broadhurst wrote that, when pumping for public baths and heating the water with the exhaust-steam, the heat lost was the amount radiated from the steam-pipes and cylinders. This amount had not been measured, but with suitable plant was very small. It had been actually tested and proved that in the winter time, when the mains water was colder than the well-water, more coal was required to heat a bath of main water than to pump and heat the same amount of well-water; but, of course, when the mains water was warmer part of this advantage was lost. It was quite correct to state that modern artesian wells were bored and finished with a single tier of lining tubes; but to make this final lining possible, several tiers of guide-tubes were necessarily used. His statements were therefore correct, together with the explanation given in his paper that "on the completion of the bore-hole, these outer tubes are withdrawn and the space can be filled with clay or cement."* A few weeks ago, 30,000 gallons per hour were obtained from a bore-hole, 12 inches in diameter and 200 feet deep, at Cambridge water-works, at Cherryhinton, by an air-lift pump. The supply was drawn from the Lower Greensand, and the total lift was 72 feet. A permanent air-lift plant was now being installed. Fissures certainly reduced the speed of cutting with the shot-drill, probably owing to shot being lost, but, although cores were frequently obtained showing considerable fissures, no case had yet occurred of the shot-drill proving unworkable from this cause. Possibly slurry, filling the fissures, might save some of the shot that would otherwise be lost. The air-lift pump, at the works of Messrs. Elliott's Metal Company, Birmingham, raises the water 230 feet, the bore-hole should be at least 500 feet deep, and actually it was 700 feet. At the station of the Central Electric Company, at St. John's Wood, an air-lift pump fixed in a bore-hole, 10 inches in diameter, raised 16,000 gallons per hour, a total lift of 260 feet. The air-lift pump, although low in efficiency, was, if well designed, not so bad as was generally supposed. The efficiency varied both with the lift and with the quantity raised. High lifts were much more efficient than low ones: this difference being probably due to pipe-friction, which was considerable, owing to the high velocity of the discharge. An average efficiency, for a lift of less than 100 feet, would be

* *Trans. Inst. M. E.*, 1907, vol. xxxiii., page 477.

40 to 50 per cent.; less than 150 feet, 35 to 40 per cent.; less than 200 feet, 30 to 35 per cent.; and over 200 feet, the efficiency might drop to 25 per cent.

The CHAIRMAN (Mr. W. G. Phillips) moved a vote of thanks to Mr. Broadhurst for the interesting account that he had given to the members of the use of artesian-bored wells.

Mr. M. WALTON BROWN seconded the resolution, which was cordially approved.

Mr. G. A. LEWIS moved a vote of thanks to Mr. W. G. Phillips for his services in the chair.

Mr. FRANK COULSON seconded the motion, which was cordially approved.

THE INSTITUTION OF MINING ENGINEERS.

GENERAL MEETING,
HELD IN THE ROOMS OF THE GEOLOGICAL SOCIETY, BURLINGTON HOUSE, LONDON.
JUNE 14TH, 1907.

MR. MAURICE DEACON, PRESIDENT, IN THE CHAIR.

DISCUSSION OF MR. A. THOMPSON'S PAPER ON "ELECTRICALLY-DRIVEN AIR-COMPRESSORS COMBINED WITH THE WORKING OF INGERSOLL-SERGEANT HEADING-MACHINES," ETC.*

Mr. PHILIP KIRKUP (Birtley) wrote that since this paper was read in June, 1906, the machines had continued to do good work; and in the first district there was, at present, over three years' work of retreating longwall opened out, in addition to the panels now working. Consequently the working of the machines had been curtailed on this account. Three further districts were now being opened out. In every case the machines were holing in the bottom coal, and it was found that this system was justified by the class of coal produced. The cost of maintenance of the machines, since the beginning of 1906, had been very low. Since then 41,510 tons had been produced, the cost of spare parts over that period had been £12 18s. 3d. for eleven machines, giving a cost of 0·07d. per ton. The workmen first put to the machines still operated them and complained of no ill effects, and now earned from 7s. to 8s. per day of 8 hours. The two air-compressors still continued to work, and since the paper was read had required practically no attention for repairs. The renewals had been nil.

Mr. J. T. BROWNE's paper on "The Thick Coal of Warwickshire" was read as follows:—

* *Trans. Inst. M. E.*, 1906, vol. xxxi., page 356.

THE THICK COAL OF WARWICKSHIRE.

By J. T. BROWNE.

Introduction.—From time to time, excellent papers and addresses have appeared in the *Transactions* describing in detail the geological formation of the important Warwickshire coal-field and its relation to other coal-areas. The writer proposes, therefore, in the following notes to deal more particularly with the methods of working the coal-seams as they occur in one particular district, together with a consideration of such problems as have presented themselves in the course of his experience at collieries in the neighbourhood.

Coal-seams.—It may be interesting, however, to compare the sections of the coal-seams, actually proved in the most recent developments on either side of the great hidden coal-field lying, roughly speaking, between the Birmingham and Nuneaton districts. Although the writer believes that the seams of the respective districts are truly correlated in the manner shown in figs. 1, 2 and 3 (plate xix.), he is bound to confess that some of the more marked characteristics of the seams in East Warwickshire appear to be absent in the Thick coal-seam of Staffordshire. This, however, is not surprising, in view of the fact that the two districts are separated by a distance of nearly 20 miles (fig. 4, plate xix.).

The so-called Thick coal of Warwickshire, so far as it has yet been proved, is somewhat limited in extent, and is formed by the thinning of the binds and shales, which, north of the village of Bedworth, separate the Ryder and Ell coal-seams. In this form it extends to Wyken colliery, at the southern end of the coal-field; but in the deep workings of that colliery the coals show a tendency to separate, and it is a significant fact that in the most easterly developments at the Sandwell Park colliery, on the Birmingham side, the same intervention of dirt-partings occurs between the coals.

It is fairly certain that the coal-seams exist, in some form or other, more or less continuously under the large tract of country at present separating the South Staffordshire collieries from those of East Warwickshire; but there is little doubt that under a considerable portion of this area, the coal will lie at a great depth, possibly cut up by faults, and by patches of barren ground.

Thick Coal-seam.—A typical section of the Thick coal-seam, now being worked at Newdigate colliery, is given in Table I., the total thickness of coal being 23 feet 9 inches.

TABLE I.—SECTION OF THICK COAL-SEAM, NEWDIGATE COLLIERY.

Description of Strata.	Thickness of Strata. Ft. Ins.	Ft. Ins.
Roof: Shaly bind ...	—	—
Seam: Two-yards Coal-seam:		
COAL, tops ...	1 3	—
COAL, hards ...	0 10	
COAL, brights	2 3	
COAL, slotters	1 8	
		6 0
Dirt	0 6	
		0 6
Bare Coal-seam:		
COAL	2 0	
		2 0
Stone	0 1	
		0 1
Ryder Coal-seam:		
COAL, windings	0 8	
COAL, spires ...	1 1	
Stone	0 4	
COAL, spires ...	2 0	
COAL, bottoms	2 0	
		6 1
Dirt	0 4	
		0 4
Ell Coal-seam:		
COAL, black ...	2 5	
COAL, spires ...	0 10	
		3 3
Dirt	0 2	
		0 2
Slate Coal-seam:		
COAL, three-quarter ...	1 6	
Batt	0 1	
COAL, bright	2 3	
COAL, bottoms	2 7	
		6 5
Floor: Clunch	—	
		—
Total		24 10

The shaly bind above the Two-yards seam is exceedingly friable, and it is generally necessary to leave up the tops coal as a roof; although it is sometimes possible to get a little of this in the wastes. The chief characteristic of this seam is the layer of spiry coal, known as "the hards," which occurs consistently throughout the district under the tops, and somewhat resembles anthracite in texture and quality. The remainder of the seam provides a house coal of excellent quality.

The Bare coal-seam is not worked usually, being somewhat soft and dirty; and the Ryder seam, although inferior and full of stone and iron-pyrites near the outcrop and towards the north, is, at Newdigate colliery, at a depth of 1,600 feet from the surface, a good hard and bright seam.

The Ell and Slate coal-seams (sometimes known as the Nine-

foot) are fairly constant in quality and thickness throughout the southern part of the coal-field, except at Wyken colliery, where the Ell coal-seam reaches a thickness of 5 to 6 feet. The bottom parting of the Ell seam consists of hard spires, and is in good demand for annealing and similar purposes.

The Slate coal-seam, so-called from the thin band of slaty batt occurring below the Three-quarter coal, contains several layers of bright coal, which are sold for domestic use; but the larger proportion of the produce of this seam is disposed of as locomotive coal and for general steam-raising purposes.

The chief considerations in deciding upon a system of working this Thick coal-seam are:—(1) The liability to gob-fire; (2) the absence of packing material; (3) the presence of water; and (4) the gradient of the mine.

Gob-fires.—Like its sister seam of South Staffordshire, all the constituent seams of the Thick coal-seam of Warwickshire, whether worked singly or otherwise, are liable to gob-fires. The writer does not propose to enter closely into the theories of chemical action which have been advanced at various times to account for the undesirable properties (possessed by some seams) of promoting spontaneous combustion; but, with a fairly long experience of Warwickshire gob-fires, he believes that the following causes are chiefly responsible for them:—(*a*) The friction due to the crushing of ribs and pillars of coal; (*b*) the oxidation of the organic constituents of the coal; and (*c*) the presence of iron-pyrites in the coal. Undoubtedly these several forces combine; but in certain circumstances any one of them may be, in itself, sufficient to generate enough heat to cause combustion.

(*a*) There can be no longer any question that the heat mechanically produced by the crushing of the coal at opening-off ribs and by the side of pillars of coal is one of the chief factors contributing to spontaneous combustion. Fires are generated most readily in the Ryder seam, and on leaving the rib-side in this seam, working on the longwall system, the writer now makes a practice of banking-up to the coal with incombustible material, such as sand or boiler-flue dust; and he believes that it has, to some extent, acted as a deterrent.

In support of this theory of crushing, the writer may instance

a case which came under his observation at Griff colliery, a few years ago. In a certain district, where the measures rise at an inclination of 1 in 6, the Ryder coal was being worked simultaneously with and in advance of the Two-yards seam.

For commercial reasons it became necessary to cease working the Ryder seam, with the result that fire broke out, without exception, whenever the Two-yards face reached the point at which the Ryder coal had been abandoned.

In the same way, at Newdigate colliery, where, owing to the depth, the weight on the seam is exceptionally heavy and the crushing severe, intense heat is generated in the Two-yards seam when the faces arrive at the Ryder rib-side; and it is only by the application of a good supply of cool air that fires can be averted. It must be borne in mind that, as the weight comes on and the gob-spaces become more and more confined, the gases are subjected to considerable pressure, and conditions are brought about which are highly conducive to the generation of further heat.

(*b*) In working seams of this character on the longwall system, especially when they contain a large proportion of moisture and volatile matter, some of the gob-material is necessarily of a combustible nature; and this, as well as the coal around, is continuously subjected to the oxidizing action of the atmosphere.

The writer has frequently observed, in working the Slate and Ell seams with solid Ryder coal above, that although heat has been generated in the wastes, actual fire has not occurred until, owing to excessive weight or insufficient packing, the Ryder seam has broken down in the goaf and exposed a large surface-area of the coal.

(*c*) The floor and partings generally contain a large proportion of moisture, apart from that in the coal itself, and this moisture, together with the humid atmosphere prevailing in the gobs, is sufficient to decompose any iron-pyrites existing in the coal, and then it becomes a powerful auxiliary in the heating of coaly matter in its vicinity.

At Newdigate colliery, the Two-yards seam, which is practically free from pyrites, has been worked singly for several years without showing any sign of fire; while at Griff colliery,

1½ miles away, the same seam worked singly, but containing in places a small proportion of iron-pyrites, some of which finds its way into the goaf, is subject to occasional gob-fires, although the wastes are well filled up.

Many experienced colliers assert that the oily shales which form the partings between the seams are mainly responsible for the generation of heat; but, although it is true these shales are often found to be steaming, it is more likely to be (in the early stages at any rate) the effect of heat rather than the cause.

From a practical point of view, the prevention of gob-fires under such conditions is well nigh impossible, but a great deal can be accomplished in this direction by avoiding, as far as possible, the occurrence of heavy falls in the goaf and the consequent exposure of a large surface of coal; and by completely isolating, by means of cross-packs of incombustible material, any small pillars or ribs of coal, which have been left, purposely or otherwise.

Ventilation should be supplied at a low pressure, so that there may be less tendency for the air to be drawn through the goaves, the necessary quantity being made up by an increased number of intake-airways to the coal-face.

A straight line of face of fair sectional area, free from cuttings, falls, and other obstacles, is perhaps the most important condition of all; but in the working of a thick coal-seam such perfection is seldom attained.

The methods of dealing with gob-fires when they do occur, are few and simple: the chief point being that they should be tackled promptly, and the minds of pit-officials should be impressed with the fact that no such thing exists as a fire which is "not serious."

Complete exclusion of air by means of cross-packs, well sanded and made solid, generally meets with success, and very often prevents the spread of the fire, which inevitably happens when valuable time is lost in trying to fill out the burning material. However desirable it may be to employ the latter method of dealing with fires on main roads and in similar places, efforts so spent upon a gob-fire in Warwickshire are almost certain to be futile.

The writer is not a believer in the application of water, unless, aided by the dip of the mine, the fire can be completely

drowned. Sometimes, when the heat is so great as to prevent approach to the seat of the fire, the water-hose may be used in order to cool the place sufficiently to enable men to work; but great caution should be observed, and sufficient fresh air immediately supplied to carry off the dangerous gases which may result. Large coal-areas have been successively worked in the neighbourhood, where, with a considerable dip and retreating faces, sufficient water has been present or available to fill the goaf completely, and such a state of things presents the most favourable conditions under which the seams can be worked.

The foregoing remarks refer only to the occurrence of fire at the working-face, trouble of this kind being somewhat rare in the pillars between main roads; but the opinion may be expressed that, in forming main roads which may have to stand for many years as intake and return-airways, it is advisable to work out the whole of the top seam for a sufficient width, filling up the space with solid packing. However bad the roof may be, a good road will be made eventually by ripping, and this will not only be free from the danger of fire, but, where there is considerable crushing, it will be a cheaper road to maintain, in the long run, than where coal-pillars are left.

Working the Thick Coal-seam at one Operation.—The seam may be worked by (*a*) fore-winning to the dip or by (*b*) driving jigs to the dip.

(*a*) *Fore-winning to the dip.*—It will be seen, that in the choice of a system of working, due regard must be had to the probable occurrence of gob-fires; and the system which commends itself most strongly is that of fore-winning the coal by means of driving out heads to the dip-boundary, or some convenient distance from the shaft, and working home.

It is not always practicable or expedient, however, to drive to the boundary, but each panel of work so developed should have a separate existence, and provision should be made for entirely damming it off when worked out or abandoned. Fig. 5 (plate xix.) shows a district actually at work which has been opened out on these lines at Newdigate colliery. The level was driven out from the side of the main hill; and from this, at intervals of 400 to 500 feet, hills have been driven down on the

full dip for a distance of about 1,000 feet, and heads driven across the bottom to form faces of work in the seams. Three lines of face are at work, the Slate coal in advance, followed by the Ryder seam, 45 or 50 feet behind, and the Two-yards seam at a further interval of about 35 feet. The spires of the Ell seam form a tough roof to the Slate coal, and are taken down between the packs whenever possible, while the Bare coal is left in permanently, first as a roof to the Ryder seam, and then as a floor for the Two-yards seam. The system of working will be made clear by reference to the plan and the section (figs. 6 and 7, plate xix.).

It is usual to drive the gate-roads and hills in the Ryder seam, thus leaving a considerable thickness of coal both below and overhead. In order to save excessive dinting, and consequent high and dangerous places at the bottom of the hills, the road is carried directly to the Ryder face, to which point the coal from the other seams is brought by means of the congates or level roads, thirled across from one seam to the other. In spite of the coal left as a roof in the Two-yards stalls, the bind roof is so bad and so liable to break down, that it is advisable to divide the places into short lengths of 150 feet or thereabouts in order to keep the face constantly moving. Six or more separate sets of men occupy the stalls so formed, and with a full complement of workers, 150 to 170 tons per shift is sent out of each hill.

It may be remarked that the hills from the main haulage-level to the face, when properly driven, require few repairs; and, whenever it becomes necessary to rip the roof or dint the floor, the product is coal in each case. It will be observed from the section (fig. 7, plate xix.) that the lower seam, the Slate coal, is devoid of any packing material beyond what is produced from the dirt holing; and it is highly necessary that builders of rock or bind shall be imported from some other part of the pit.

One of the advantages of this system of working the coals simultaneously is that plenty of suitable material is available from the Two-yards goaves, and this is systematically filled and conveyed during the off-shift into the Slate-coal stalls for the use of the men.

In the Ryder seam, however, it is the custom of the district to fill the coal with forks and to gob the slack; and, however reprehensible this practice may appear, no evil results are

specially noticeable. This slack, together with the holing dirt and the stony parts of the seams, provides sufficient material for effective packing.

In the older collieries near the outcrop, where the seam lies at a considerable angle, better advantage was taken of any water which might be available for closing the wastes; and, in addition, it was possible to throw back the roof-weight better and with more effect than is practicable where the mine is less inclined. The result in the latter case is that where packs are not properly built, the roof cuts off at the face-side and trouble arises in the seam that is following behind.

Experiments have been made in the district, with the view of getting out more coal per acre, by simultaneously working the seam divided up somewhat differently; and this system was successfully employed at Wyken colliery, where the Ell coal is thicker; but, on the whole, the division described is fairly general.

(*b*) *Driving Jigs to the Rise.*—It is sometimes necessary to get coal lying to the rise of the shaft-bottom, and in such cases it is usual to drive out a level and counter-head in the solid coal with a pillar, 75 to 100 feet thick between them, cross thirls being driven to the rise at right angles to the level at intervals of 300 feet or less. The three seams are then opened out in exactly the same way as already described, the gates being carried forward as the faces move up.

Where there is sufficient gradient for the haulage to be self-acting, the cost of working is low in this respect; but this advantage is outweighed by the difficulty of getting material up the jigs to deal with gob-fires should they occur. Although by this system a face of working can be more quickly opened out, the subsequent cost of ripping the jigs and dealing with the spoil is heavy; and it is certain, in most cases, that the pillar left for the support of the haulage-level will be lost.

Separate Working of the Seams.—The immunity from gob-fires while working the Two-yards seam, which is commercially the most valuable, has on more than one occasion tempted colliery owners to work this seam first, leaving the others to a doubtful fate; but, while there may be questions of expediency to consider, the writer is not prepared altogether to condemn the

system from a practical point of view. The obvious advantage is that the most valuable seam is secured with possibly a smaller percentage of slack, the work being opened out on the fore-winning system or by means of jigs to the rise. One of the disadvantages is that another set of roads must be driven to develop the Slate and Ryder seams at a later date, with a possibility of losing the latter.

The writer is now working, on the retreating system, a panel of the lower seams in a part of the mine where the Two-yards seam was worked four or five years ago. It is, as yet, too early to say definitely whether the coal can be worked as cheaply as by the alternative system; but at present the seams are somewhat dead owing to the absence of top weight. A further disadvantage lies in the absence of packing material, which must be hauled from some other part of the pit and sent down the hills. As an experiment, hills have been driven down to work the Slate coal first, leaving the upper seams intact; but here again one meets the problem of providing packing material, while there seems little doubt that the other seams will be badly broken up and difficult to get.

It is not claimed that the above modifications of the fore-winning system are the most suitable in all cases. Large areas of coal have been worked successfully elsewhere in Warwickshire, where only two main hills have been driven to the dip, an intake and a return-airway, to deal with the output from faces up to 1,800 feet wide, the Slate and Ryder faces being used as haulage-roads, but there are obvious drawbacks to this arrangement where the faces are liable to break down.

There can be little doubt, from an economical point of view, that the simultaneous working of the seams in three (or possibly four) retreating faces is the system which possesses the most advantages; but one must not lose sight of the fact that in the most recent developments the coal-field is approaching the bottom of the basin, and with a reduced dip the difficulties of applying this system are certain to increase.

Haulage.—In describing the systems of haulage employed in this part of Warwickshire, it may be well to point out that the dip of the seams is very rapid at the outcrop, gradually decreasing towards the west, and the natural tendency on the part of colliery

proprietors has been to sink the shafts as far to the rise of the royalty as possible. The result of this arrangement is that, in most cases, the entire output of the colliery is eventually brought to the shaft-bottom by one or two main roads. Mining engineers have not been slow to recognize the importance of an efficient system to cope with these conditions; and, even amongst the older collieries in the district, haulage-plants are to be found which will compare favourably with the most recently laid down arrangements elsewhere in the kingdom.

Systems of main-rope and endless-rope haulages driven from the surface or by power transmitted to the pit-bottom are in general use for these main haulages, and in some cases auxiliary mechanical haulage has been carried to the working-faces to the entire exclusion of ponies.

The writer will describe one or two arrangements laid down by himself, which, though perhaps devoid of originality, are interesting examples of subsidiary haulage designed to meet special circumstances. Fig. 8 (plate xix.) shows the dip-workings in the Two-yards seam at the Clara pit, Griff colliery. The shaft is sunk to the Seven-foot seam, and the Two-yards seam is reached, at A, by a level stone-head driven a distance of 900 feet across the measures. The road is then carried down in the seam at the normal dip of 1 in 6 for a further 250 feet, and levels are driven out on either side. From this level, at intervals of 300 to 350 feet, hills were originally driven down in the coal to the dip, a distance of about 1,200 feet: these being gradually shortened towards the end of the level, in order to enable the farthest stalls to work first out to the level.

The motive power is compressed air, and the main haulage is dealt with by a hauling-engine, B, with two cylinders 13 inches in diameter, fitted with two drums and main-and-tail ropes. The tail-rope pulls the empty tubs from the pit-bottom over the brow of the hill, and passes round a pulley fixed in the roof at C, where a boy unhooks the rope, and the train, going forward by gravity, takes in the main rope with it. On the return of the main-rope with the full journey of tubs, the tail-rope is hooked on behind, and taken out to the pit-bottom ready to repeat the operation. The main train of empty tubs is driven to a flat on either side, where a single-drum hauling engine, D, with two

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as previously described.

Conclusion.—In submitting the foregoing observations to the members, the writer does not suggest that the approved methods of working the Thick coal-seam of Warwickshire, which he has described, are incapable of modification, or that the important problems connected with it have received in this paper the full consideration to which they are entitled.

Possibly conditions may arise in future developments necessitating the adoption of some entirely different method of working, such as the Staffordshire square work, or the pillar-work employed in parts of Scotland; and it is chiefly with the object of inducing members, who are interested in the working of thick coal-seams, to join in a discussion of the subject that this paper has been written.

Mr. Alexander Smith (Birmingham) said that this paper appealed to him, because his interests were largely those of the [illegible] as their agent, and the system which Mr. Browne had so [illegible]ained, of working the Thick coal at great depths, was [illegible]o produce more coal than any other system that he [illegible]. Browne had not touched upon the difficulties of South [illegible]here the Ten-yards seam, at a moderate depth, was [illegible]ib-and-pillar system, taking out comparatively [illegible]l after going in four or five times bringing out [illegible]e whole; but, when it was worked at depths of difficulties commenced, and as a result only [illegible] coal was worked and the remainder was left. The [illegible] large hollows had been so terrific that miniature earthquakes had closed the roads in the solid coal as fast as they were made. At Hamstead colliery, they had a further calamity; and, although what was thought to be sufficient pillars were left, spontaneous combustion had ensued, and a fire near the shaft had resulted in the colliery being closed. Later, the seam was recovered from a fresh inset, a long way above the fire-area, but the process of recovery was a very difficult and expensive matter. There were capable engineers in Warwickshire, who would grapple with the difficulties of fire and weight, and he hoped that they would work the seams in the manner described by Mr. Browne.

Mr. H. R. Hewitt (H.M. Inspector of Mines, Derby) said that although Mr. Browne agreed that the East Warwickshire coalfield was identical with the Thick coal-seam of Staffordshire, yet there were some differences in the more marked characteristics. He (Mr. Hewitt) would like to know in what particulars they differed, and to what extent; and, in discussing this paper, it was necessary that great attention be paid to the sections (figs. 1, 2 and 3, plate xix.), and also to the depths at which the coal-seams were worked at Newdigate colliery. The packing of the goaves of the Warwickshire mines, where all the seams came into close proximity with each other, was always performed in a somewhat unsatisfactory manner. Fig. 6 (plate xix.) showed the packing of the stalls as it should be done, but he had seldom seen it done so well in practice. Packing material was admitted to be scarce, and it appeared, therefore, that they might follow a practice of

cylinders 8 inches in diameter, is fixed. At the far end of each level, a similar engine, E, is fixed, and the ropes from these two hauling engines act in see-saw fashion, alternatively as main-and-tail ropes in taking in and bringing out the trains of tubs. The same results could, of course, be achieved by a single main-and-tail rope hauling engine, but the roads in question, like most Warwickshire levels were not driven absolutely straight; and, in addition to this, some difficulty would have been otherwise experienced in picking up and setting down tubs at the hills.

Each hill has a separate hauling engine (fig. 9, plate xix.) drawing 4 or 5 tubs from the working-face. The full tubs are placed upon the main road in readiness to be picked up by the level train as it comes out. The empty tubs are similarly dealt with on the inward journey, and by regulating the supply of tubs the system has proved most efficient.

A modification of this arrangement on a smaller scale is in use at Newdigate colliery; but there, advantage has been taken of a slight rise in the level which allows the train of full tubs to gravitate towards the main hillside bringing with it the rope, attached to the drum of an electrically-driven haulage-gear placed at the inbye end of the level. Where the gear has been provided with a brake powerful enough to control the speed of the full train, this system works well. The empty tubs are dropped off, and full ones picked up at the tops of the hills in the same way as previously described.

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their Continental neighbours by working stone at a surface quarry for sending into the mine where all the stalls are to the dip of the shaft, to be used for packing the goaves, instead of using bituminous shales, which were subject to spontaneous heating after being disintegrated by the pressure due to the removal of the coal. The amount of coal lost in working the Thick coal-seam of Staffordshire was very great, and it was probably for this reason and the peculiar condition for ventilating the working-places, that the Staffordshire system of working had never been applied to the thick section of Warwickshire. The main coal of South Derbyshire, 14 feet thick, was subject to fire. The lower 8 feet was worked on the main face and the upper 6 feet was got in the wastes between the packs only, and when the first symptoms of fire were noticed, by the deposition of small globules of moisture in the waste, a cross-pack was placed across several wastes, built in with flue-dust or sand; the greater portion of the packing-material used was the white sandstone rock overlying the Eureka coal-seam worked some distance away, and it was the use of this packing-material which had removed so much anxiety in working the Main coal-seam of South Derbyshire.

Mr. J. H. W. Laverick (Sheffield) said that, after lengthy experiences in Nottinghamshire, Derbyshire, and elsewhere, he found that as good packing as he had seen anywhere was used in the Slate coal-seam of Warwickshire. The packing of the other seams at the back of the Slate coal-faces was difficult, because the material, employed for packing, was very tender. The difficulty might be overcome in some measure by bringing stone from the upper seam to help to fill up the wastes. The working of the Thick coal of Warwickshire presented unusual difficulties at a depth of 1,500 feet. The hill system of working was not new: it had been successful, from a practical point of view, in the case of shallow mines, near to the outcrop, where the measures were not too flat; but, as the depth increased, the pressure also increased, and the difficulties increased enormously. After two years' work in Warwickshire, he was of opinion that it was desirable for the Two-yards or top coal only to be worked in one or more districts of the pit, owing to the freedom of this seam from spontaneous combustion, and the débris from that or those districts could be used for packing in a district where the full section of the Thick coal-seam was worked.

Mr. W. G. Phillips (Atherstone) said that at the Ansley Hall collieries, these thick seams of coal were divided by 135 feet of strata, and he appreciated them very much better in that position. The Two-yards seam at Newdigate colliery was a very excellent quality of coal; and in any system of working the thick coal at Newdigate colliery, regard should be had for the superiority of that coal and the enhanced price which it realized—a very important factor. In working the Slate coal in advance and the Ryder coal following, 45 to 50 feet in the rear, the overlying Two-yards coal (fig. 5, plate xix.) would suffer from the crushing effect of the goaf, and the underlying adjacent workings; and the average selling price of the Ryder coal, owing to the greater percentage of slack, would be materially reduced. He thought, if he might be allowed to say so, that the working of the Slate coal, underneath the Ryder coal, had taken place rather too soon after the working of the Ryder coal, to render it an advantage to work the Slate coal by the retreating system. If this had been deferred for 10 years or so, until the goaf had settled down, the effect of the weight on the Slate coal would be the same as though the Two-yards coal had been left unwrought. He thought that it would be possible to combine the two systems, taking out the Two-yards coal by the ordinary system of working; but, instead of driving out levels, to follow the somewhat modified course that they had adopted at Ansley Hall collieries, of driving heading stalls, 75 feet wide, and taking out all the coal: ultimately adopting the system shown in figs. 5, 6 and 7, for the working of the Slate coal. He understood that the Ryder coal was not a valuable coal. From his observations in Warwickshire, extending over 30 years, he considered that packing in Warwickshire compared very favourably with that of other parts of the country working steep seams. He did not think, from an economical point of view, that it would be possible to quarry packing material on the surface and send it into the mine, as the cost would be too great.

Mr. H. S. Smith (Timsbury) said that at the Himley collieries, some years ago, an attempt was made to work the Thick coal-seam in two sections, but it was not successful. This system and a modified longwall system had been described in the *Transactions*.*

* "A General Description of the South Staffordshire Coal-field," etc., by Messrs. W. F. Clark and H. W. Hughes, *Trans. Inst. M. E.*, 1891, vol. iii., pages 38 and 40.

At Sandwell Park colliery, the Thick coal-seam was worked on the rib-and-pillar system, and it was stated that practically all of the ribs-and-pillars would be abstracted at some time in the future; but he thought that, when worked, both there and at Hampstead colliery, a large proportion of the coal would be lost. He was of opinion that, if the longwall method of working the Thick coal-seam of South Staffordshire were adopted in Warwickshire, it would probably be found to work successfully.

Mr. Henry Hall (H.M. Inspector of Mines) said that, in North Wales, where slate, a very valuable material, was mined, only about half of it was worked. A chamber was driven, about 45 feet wide, and a pillar, 45 feet wide, of the valuable material was left, and so on. He would like to know what proportion of the Thick coal-seam was worked in Staffordshire, as it appeared to him that a considerable percentage was left in the mine. The landlord fixed how much of the slate was to be left, as a "crush" was a most serious matter; and, when the surface began to move, the mountain began to slide downhill very rapidly and covered up the access to the mine.

Prof. A. Lupton, M.P., who made his first acquaintance with Warwickshire and with South Staffordshire 40 years or more ago, thought that the Thick coal-seam of Warwickshire was worked in a different fashion from that of South Staffordshire, owing to the fact that it had a steeper inclination near the outcrop, and the Staffordshire Thick coal-seam was found nearly level at a moderate depth. The difference between level and steep seams would account to some extent for the different methods of working the Thick coal-seam, and the systems would be followed up, as it was very difficult to change a system. Solid stowing was generally adopted in France in the working of thick coal-seams. The stone was quarried on the surface, and in some places dropped down a pit used for that purpose; the tubs, loaded with stone, were taken to the working-face; it was emptied there, and the coal was loaded into the tub which had brought the stone. In France, surface-owners were entitled to support, and could claim considerable compensation if the surface was damaged. Possible claims for surface-damage constituted an important reason in deciding a French colliery-manager to adopt a system of complete stowing. There could be no doubt that to stow a mine economically with material

from the surface, the mine must be laid out with that object, so that it could be done with a minimum of labour. He thought that the time would come when a great deal of stowing material would be sent from the surface into British mines.

Mr. S. F. WALKER (Bath) suggested that carbon-dioxide, dissolved in water, would provide a ready means for reducing combustion if it had broken out, and it would also, under certain conditions, prevent the outbreak of fires. The use of water was possibly objected to, because it would carry heat along and start combustion somewhere else. He suggested, therefore, that if water were sprayed on the fire they would probably get rid of that difficulty.

Mr. C. C. LEACH (Seghill) was of opinion that Mr. Walker had never seen a gob-fire. It would be most dangerous to spray large volumes of carbon dioxide on a fire, and it might lead to the loss of many lives in a mine. He had seen a fire in a mine that had been burning for about 40 years; he did not want to see it again, but there was no intention of trying to extinguish it with carbon dioxide, owing to the danger to life involved in such an attempt, together with the prohibitive cost.

Mr. H. S. SMITH (Timsbury collieries) said that a modified system of Thick coal longwall working had been successfully worked in a seam dipping 1 in 3. The seam was worked in the reverse direction to that followed at the Newdigate colliery. The main roads were driven to the full rise of the seam, and the working roads were driven level on the strike. The best method, in his opinion, of preventing gob-fires was to keep the coal-face constantly moving; and, when a fire did occur, it could be isolated by means of a rib of coal.

Mr. F. C. SWALLOW (Hednesford) said that it was only within the last 10 or 15 years that much attention had been given to the difficult question of working thick coal, lying flat or at a small angle of inclination, at considerable depths, and subject to spontaneous combustion. He did not believe that there was any system whereby all the coal could be extracted. Mr. Browne stated that the retreating system could be worked successfully; but he suggested that this system could only be successfully adopted where gob-fires could be drowned, aided by the dip of

the mine. He believed that a system of water-sprays was in use at Hamstead colliery for initial fires, but it was only used in emergencies; where possible, the fire was dug out or choked by packing with sand or boiler-flue dust, and this appeared to be the best practical means of successfully dealing with gob-fires.

Mr. M. W. Waterhouse (Bedworth) said that Mr. Browne gave three reasons for the occurrence of gob-fires, but had not referred to the colliers' objectionable habit of leaving props in the goaf. A prop, say, 8 inches in diameter, soon became a mass of splinters, like matchwood, and formed a convenient centre for originating a gob-fire. He agreed with all the rules proposed by Mr. Browne for the avoidance of gob-fires, but he thought that Mr. Browne might have added the advantage of travelling the face forward at a great speed. In one thick seam, the working-face advanced at the rate of 66 feet per month; and it had been working for 8 or 9 months, without a vestige of gob-fire being seen; but at an ordinary rate of advance, numerous fires would have occurred. Mr. Browne discussed the desirability of avoiding the occurrence of heavy falls in the goaf and the consequent exposure of large surfaces of coal to the danger of spontaneous combustion. He agreed with this recommendation, but he had recently been compelled to work a large area of coal, that had been somewhat badly treated by nature, and it was impossible to prevent falls, as the strata formed one mass of joints and fissures. Mr. Browne did not mention the use of rescue-appliances in connection with pit-fires, but that had always appealed to him as a desirable method. He rather favoured their use until, a few years ago, he happened to hear that a few lives had been lost through the use of such appliances, and he realized that their use in Warwickshire mines might prove dangerous on account of the difficulty, generally experienced, of introducing new apparatus. Mr. Browne did not believe in the application of water in large quantities, but he had found that small quantities of water were most useful. They had to be small, owing to the great distance from the supply. A tub of water, a 3-gallons fire-extinguisher of the Merryweather type, and a few spare charges, would make better progress in extinguishing a small fire than any other method, especially when digging it out, where it was practicable. He believed that he was correct

in stating that the Thick coal-seam in Warwickshire had not been worked at depths exceeding 1,500 feet until 4 or 5 years ago; and, therefore, any experience obtained or observations made with regard to other collieries, which had worked the Thick coal-seam, would not apply to the present conditions, because the seams were not worked at so great a depth. He observed that Mr. Browne left in ribs of coal, at the sides of the flat, in the Slate coal-seam (fig. 6, plate xix.) He (Mr. Waterhouse) had been compelled to leave similar ribs, in the case of roads driven prior to his time, and he found that the leaving of these ribs was most disastrous. The road, passing through them, was in a continual state of upheaval; and it would rise as much as a foot in one shift. All new roads were now so driven, as to avoid having to leave any pillars in the Slate coal-seam. It was obvious, notwithstanding any slight advantage that might be gained in the reduction of gob-fire and timber-costs, that it would not afford adequate compensation for the enormous expenditure required to quarry stone for packing material and take it into the mine. Mr. Browne stated that it was possible to produce from 150 to 170 tons per shift from each hill; many members would be glad to do the same; but he (Mr. Waterhouse) had found it sometimes desirable to nearly double these figures. Where the dip was great, an accumulation of water was an advantage in extinguishing fires in the gob. In his own experience, if one was troubled with water, the dip was always too slight to take it away; and if one wanted water to extinguish a fire it was not available.

Mr. L. Holland (Hamstead Colliery) wrote that the difficulties of working thick coal by the longwall method were innumerable, including scarcity of packing material and frequency of gob-fires, with the risk of losing a district (and consequent reduction of output) until a new face could be opened. In square work, on the other hand, the sides of work or panels were cut out in such areas as could ordinarily be worked out completely before taking fire; and before the side of work was finished the rib was being cut off for the new side, so that if the old side should fire before it was completely finished, the new side could be worked double shift. As a matter of fact, if carefully watched, there was seldom any loss of output from this cause. In working the seams separately, it might be convenient for certain

reasons to work the Two-yards seam first, but it was certainly inadvisable, having regard to future workings; and unless the gob was packed solid and without wastes, one would expect that the Ryder seam would be lifted and broken, and a very bad roof would be left for the lower seams. He (Mr. Holland) had a somewhat similar experience to that of Mr. Browne's in the South Staffordshire Thick coal-seam, in working the bottom part of the seam where the top coal had been worked previously, all above the Stone coal being removed. The Stone coal was left as a roof, and the remaining thickness of 5 feet of coal was worked. Close timbering was necessary, but even that was not sufficient to prevent the gob from running in and burying the face in places where the coal was severely crushed and small knobs of coal had to be left to catch the roof again. Where the floor of the top roads had lifted and had been lowered, the bottom coal on each side was crushed to fine slack and was the cause of fires. The labour-cost per ton in this district was excessive in comparison with the cost in other districts, worked by the square-work method. Where thick dirt-partings or inferior and hard seams of coal occurred in the Thick coal-seam there might be some advantage in the longwall method of working; but in working thick coal, as it occurred in South Staffordshire, with very thin partings and all good saleable coal, it was generally agreed that, of the many systems of working, the square-work system was the most suitable. Where thick coal occurred at a depth of 1,500 feet or more, the initial temperature of the coal was necessarily high, and if the coal were very liable to spontaneous combustion it was certainly minimizing a serious risk if the work was cut up into panels, whatever method of working might be adopted inside those panels, so that in case of a fire which could not be removed, it could be dammed off effectually and cheaply, and the loss of coal and workings would be confined to a small area. In deciding whether to work longwall or square work, inside those panels, there were several advantages to recommend square work. The opening-up for work would be much cheaper, the output per man would be much greater, and the removal of dirt for packing would be avoided.

Mr. R. Kirkby (Prestonpans) wrote that he agreed with Mr. Browne's remarks as to the probable causes of spontaneous

combustion in coal-seams. In the Chemiss seam in Fife, several fires were found to be due to two distinct causes, namely: (*a*) heat caused by crushing of pillars or ribs of coal left in the waste; and (*b*) chemical action. At a depth of about 500 feet from the surface, two separate fires were undoubtedly due to the crushing of narrow ribs of coal, abandoned owing to the expense which would have been incurred in repairing roads to work out the coal. The coal, at these places, was good and free from iron-pyrites or other foreign matter, so far as could be seen. In this same seam and in the same colliery, at a depth of about 1,000 feet, there was a very good illustration of a spontaneous fire from heat caused by chemical action. A section or district of coal had been worked in the ordinary way. The dip was 1 in 6, and the main roads were built through the waste straight to the rise. Side-roads were branched from these main roads at right angles, every 30 feet. A fire was discovered in the waste between two of the side-roads, and it was dug out and filled into tubs. In the course of this operation, a considerable quantity of white spar was found in the burning rubbish. This spar was found in this seam in the form of vertical veins from 1 inch to 4 inches thick. The coal was clean for a considerable distance, then a series of these veins were found, running in the direction of the main backs or cleat of the coal, and shortly again the seam was got clear and free from them. The miners cleaned the coal, and stowed the spar along with small coal and a thin top stone or fire-clay parting. This fire extended from one roadside to the other, and was about 10 feet in width. It was totally cleared away, and the place left supported on trees.

Some time afterwards, another fire was discovered in the next waste, between the second and third roads, and in a straight line with the first fire. This second fire was dealt with in the same way, and the white spar was again found at the hottest part. The roof of the road, separating the two fires, was quite solid. It should be stated that the roof was inferior coal about 2 feet thick.

A week or two afterwards, a third fire was found between the third and fourth roads, and another between the fourth and fifth roads. These were all in a straight line, and the roof was not broken in the wastes or in the roadways. There was no water or even dampness. The whole area was very dry. This spar had not been analysed, but there was probably soda in it.

So far as could be seen, the wastes in which these fires took place contained this foreign material, and the other wastes, in other parts of the neighbouring workings, were clear of it.

According to his (Mr. Kirkby's) experience, water was of no use in extinguishing fires *in situ*, unless, of course, the section of work could be drowned. If the burning material was to be filled away, then, let them by all means, use water, if possible, to cool it before putting it into tubs. This could not always be done, and it was often only possible to cool the rubbish by throwing it into the tubs in two or three casts. Where a seam was liable to spontaneous combustion, the question whether the pavement or floor was of a soft or a hard nature was the deciding factor as to fires or no fires. The Dysart Main seam, at one colliery in Fife, had a soft fire-clay pavement, 3 or 4 feet thick; and although now and then a place heated up slightly, there was never a fire in that pit. The pavement soon heaved and met the roof, and the heat was smothered. In the neighbouring colliery, only one mile away, the pavement was hard. The change took place gradually, the 4 feet of fire-clay altered to 1 foot of hard stone, and a coal in the pavement, 18 inches thick at the first colliery, became 3½ feet thick a mile off: this pavement did not heave, and there were fires in that colliery almost constantly. In both the Dysart Main and the Chemiss seams, a road driven in the solid coal, if allowed to remain undisturbed, would, in a few years, often be found to have a deposit on the coal-surfaces of white spikey crystals of sulphuric acid and water, which looked like cotton-wool at a distance of a few feet. He had never seen this in any other seam not subject to spontaneous combustion, and he would be very much interested to learn whether Mr. Browne had noticed anything of the kind in Warwickshire.

Mr. H. Johnstone (H.M. Inspector of Mines, Stafford) wrote that Mr. Browne made no reference to the "bumps" or sudden weighting and breaking of the roof, which formed such an element of danger in the working of the Ten-yards coal-seam in South Staffordshire. If, as he presumed, these were less frequent or more easily dealt with in Warwickshire, it would be interesting to know the reason. This was probably to be found, not so much in the nature of the seams or in the methods of

working them, as in the nature of the overlying strata. Could Mr. Browne favour the members with a section of the strata, and also with a statement of the depths to the various workings described? Mr. Browne referred to outbreaks of fire, when the working-face of the Two-yards coal-seam overtook that of the Ryder coal-seam: were these outbursts in the Two-yards or in the Ryder coal-seam? If the latter, was the working-face left standing open when it was abandoned? Mr. Browne also referred to occasional outbursts of fire in the Two-yards seam at Griff colliery, while the same seam worked at Newdigate colliery showed no signs of fire. He attributed the immunity of the latter working to the coal having been practically free from pyrites. Could he inform the members whether the depths and conditions of working were exactly similar; whether the gobs were equally stowed or packed; and whether the small coal was filled out or left in the mine?

Mr. Thomas H. Ward (Giridih, India) wrote that Mr. Browne had described a most interesting system of working thick coal on the longwall principle. At first, a South Staffordshire thick-coal man would instinctively feel that, if a face of such great length as that shown in fig. 8 (plate xix.) were opened out in South Staffordshire, it would lead to enormous waste of coal in the shape of ribs left for damming off gob-fires. In fact, he would be inclined to say that such a system was impossible in a coal-seam so liable to spontaneous combustion as the South Staffordshire Thick coal-seam. He (Mr. Ward) was of that opinion on reading the paper, but further reflection and careful consideration of the facts adduced by Mr. Browne as to the causes of gob-fires under sub-head (*a*), and his description of the methods found effective in dealing with these fires, suggested an entirely opposite conclusion. Mr. Browne gave a most prominent position, as a cause of gob-fires, to the heat mechanically produced by the crushing of the coal at "opening-off" ribs, and by the side of pillars of coal, and adduced an interesting instance. It was everyone's experience in South Staffordshire that a fire would start on the side of a road, or in a solid pillar; and it was a common practice to hole and stow 6 feet on each side of gate-roads, so as to ease the pressure and reduce the risk of fire.

It needed no argument to demonstrate that, when a mine

had been laid out on the South Staffordshire square-work system, a maximum resistance to crushing was expected from the ribs and pillars forming a side-of-work. The principle relied on was, in fact, to afford direct support to the roof by the coal left in the ribs and the pillars, and thereby to gain a sufficient interval of time to enable the remaining portion of the coal to be won; and to prevent any sagging or bending of the superincumbent strata until this operation had been completed. In short, a maximum resistance to crushing was offered; and it was, therefore, clear that the maximum number of heat-units which could be mechanically produced by crushing would be evolved. In the system described by Mr. Browne, the application of the longwall system allowed the strata to bend over gradually; the weight was distributed; no attempt was made to use the coal as a direct support; and it was obvious that the minimum number of heat-units mechanically produced by crushing would be evolved.

A very pregnant question then arose, as to whether the square-work system, in vogue in South Staffordshire, was the cause of the extraordinary frequency of gob-fires; also whether it was not time for South Staffordshire workers to reconsider their position, and to ask themselves whether the very ancient system of opening out which they were following should not be revised in the light of the experience of thick-coal working in Warwickshire. He could assure the members that it was with very great surprise that he found himself arguing against the continuance of a system of work with which he was so familiar, in which he was brought up, and which he had always looked upon as the only possible method of working at depths greater than 1,200 feet. The depth at which the operations took place had always been considered a very important factor in determining the system of working which could be adopted; and in this connection he would have liked fuller information from the author. So far as he could see, the only depth mentioned was that of the Newdigate colliery, 1,600 feet. Apparently the system of work described had been carried on at that depth, as the author stated that at Newdigate colliery "the weight on the seam is exceptionally heavy and the crushing severe, intense heat is generated in the Two-yards seam when the faces arrive at the Ryder rib-side; and it is only by the application of a good supply of cool air that fires can be averted." Actual experience

had, therefore, shown that the system could be successfully applied at a depth of over 1,500 feet, and it became of the greatest interest to enquire whether better results would not have been attained at Hamstead had this system been followed.

There could be no doubt that the yield of coal from mines worked on the square system was poor; while in the system described in the paper it appeared to be very high. This, however, was not the most important point that had to be considered. The most important issue was whether or not gob-fires in South Staffordshire were due to leaving ribs and pillars; and whether or not they would be obviated if the Warwickshire system were adopted. It was something of a revelation to read that gob-fires could be dealt with "by completely isolating, by means of cross-packs of incombustible material, any small pillars, or ribs of coal, which have been left, purposely or otherwise." In the square-work system such a method could not be followed; any attempt to cut off a portion of a side-of-work was practically impossible; and the usual method was to abandon it. Dams or stoppings must be built to the full height of the excavation, and a practical limit was soon reached. Was this difficulty inherent in the system? Was it because the roof was not allowed gradually to come down? At any rate by working the seam in three lifts, as was done in Warwickshire, the roof was much more accessible. It certainly seemed to him (Mr. Ward) that it would be worth the while of coal-owners and mining engineers in South Staffordshire to look carefully into this matter. It appeared, from the experience now available in Warwickshire, that the system which was being followed in South Staffordshire was the principal cause of the gob-fires which had caused such heavy losses.

Of course, as Mr. Browne was careful to point out, one of the important considerations, in deciding whether the Warwickshire system of working could be adopted, was the available packing material. It must, however, be remembered that complete absence of packing material was not an insuperable difficulty; and it was conceivable that it might be economical to adopt a method of work which promised a notable decrease in the risks from gob-fires, and a greater yield of coal, even when no packing material was available in the seam itself; that was, when the packing material would have to be brought into the wastes.

Were he (Mr. Ward) responsible for the development of deep

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A bed of fire-clay, 12 feet thick, underlying the coal-seam, had the following analysis:—Silica, 64·4 per cent.; alumina, 23·0 per cent.; lime, 0·5 per cent.; oxide of iron, 1·4 per cent.; magnesia, 0·7 per cent.; and moisture and organic matter, 10 per cent. He (Mr. Watson) believed that this coal was of Coal-measure age. The clays and shales contained *Calamites*, *Lepidodendron*, *Sigillaria*, *Stigmaria* and other Coal-measure fossils. Thick beds of limestone, which cropped out about 8 miles north-westward corresponding in position to the Mountain Limestone, were fossiliferous and contained *Productus giganteus* and other characteristic species.

At present, this thick seam was being opened by an inclined road, 11 feet wide, driven on the full dip; at 238 feet levels were turned away right and left, and at distances of 280 and 210 feet respectively they were connected with the surface, by rectangular shafts, for ventilation. Below the first level, at intervals of 105 feet, others were turned off every 105 feet, and pillars were

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The Warwickshire system described by Mr. Browne appeared to be very suitable for this district. There would be very little filling for the gob, but this could be brought from the surface at a small cost. He (Mr. Watson) asked whether any special provision was made in the lower workings for the support of roads in the upper workings, and whether the 2 feet to 3 feet of coal left as a roof formed a sufficiently strong floor? Were the upper portions of the seam much affected by the working of the lower seam, and was a large percentage of slack produced?

The description of the electrical haulage made him very envious, when it was compared with the system at present in use at Akmolinsk: a *taratan* (horse-gin) worked, depending on the load, by one or two horses. A strong horse, 13·2 hands high, drew two tubs, each containing 8 cwts. of coal, up a gradient of 1 in 4, so that the cost of haulage was not great: especially when such a horse could be bought for about £7, and hay cost about 9*s.* per ton.

He (Mr. Watson) agreed with Mr. Browne's assertion "that heat produced by the crushing of coal in opening-off ribs is one of the chief causes of gob-fires"; and in his experience in the Shallow seam of South Staffordshire, the only fire that broke out in five years originated within 100 feet of a boundary-rib.

mines in South Staffordshire, or an owner of coal-land there, he would very seriously consider the advisability of working on the lines of the Warwickshire system. Mr. Browne diffidently suggested that perhaps the method which he had described might possibly be replaced by the South Staffordshire square-work system, or the pillar-work system employed in parts of Scotland. The paper seemed to suggest, as he (Mr. Ward) had previously pointed out, that it was the South Staffordshire men who should carefully reconsider the position.

Mr. Edward Watson (Akmolinsk, Siberia) wrote that he had read Mr. Browne's paper with great interest, more especially as he was at present considering the system to be adopted for the working of a very similar seam. All the seams on this royalty, 10 miles long and 3½ miles wide, dipped south eastward at an angle of 10 to 12 degrees, and cropped out along the north-western boundary. The Mariana seam, referred to above, was 24 feet thick, with a few bands of fire-clay, which never exceeded 2 inches in thickness and easily separable at the surface, forming partings, here and there. The seam was carefully sampled at close intervals (2½ feet) and an average analysis was as follows:—Volatile matter, 24·6 per cent.; fixed carbon, 61·4 per cent.; and ash, 14·0 per cent.

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In the meantime, in order to increase the output, whilst the main roads were advancing to the dip, experimental panels of work, to the rise of the first level, had been successfully worked. Pillars, 35 feet long and 15 feet wide, were formed next to the main level. The bottom 7 feet of coal was removed, and the roof supported by wooden chocks. These were drawn, one at a time, and the overlying 7 feet of coal was worked; and higher chocks, set on the small coal and shale left from the former working, were built. These were in turn removed, and the top section fell, the men standing between the chocks and removing the coal by rakes, in order to avoid working under the unsupported roof, which very soon fell. This system might not be practicable at a greater depth, but it was satisfactory under the present cover.

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NEW RAND GOLD-FIELD, ORANGE RIVER COLONY.

By A. R. SAWYER.

Allusion was made to the New Rand gold-field by the writer in his paper on "The South Rand Gold-field" read before this Institution in 1904.* Since then the borings have been continued, and as it may still be some time before the details of the work can be published, the writer thought that some information regarding the general geological conditions obtaining in the locality of this new gold-field would be acceptable to members. Although it may be premature to speak of the area in question as a gold-field, the results so far obtained are sufficiently encouraging for us to venture to call it so.

The locality of this gold-field has been indicated in the writer's previous paper. The geological plan (fig. 1, plate xx.) shows its relative position to other Transvaal and Orange River Colony gold-fields in the Witwatersrand system. It will be seen that the area, as a gold-field, is, in fact, entirely new, and that it is practically everywhere covered with younger Karroo beds, about 700 feet thick in that locality. The section (fig. 2, plate xx.) on the line AB of the geological plan shows its position relatively to the Witwatersrand gold-field.

It will be noticed that the sites of bore-holes in the New Rand gold-field are about 50 miles due south of the Cinderella Deep shaft on the Witwatersrand. The intervening country is more or less covered with younger formations.

The section (fig. 2, plate xx.) shows that the Witwatersrand strata in the New Rand gold-field dip, as on the Witwatersrand, to the south; and the writer considers that this is a very strong point as regards the future of this gold-field, for he has noticed instances in which the same banket-reef is more auriferous when dipping to the south than when dipping to the north.

The section (fig. 3, plate xx.) on the line CD of the geological plan gives an idea of the geological formation occurring east

* *Trans. Inst. M. E.*, 1904, vol. xxvii., page 553.

of the section AB (fig. 2, plate xx.). A bore-hole was recently put down at Schaapplaats (fig. 1, plate xx.), about 25 miles south-west from the New Rand: the section of this bore-hole has been published as follows:—

Description of Strata.	Thickness of Strata. Feet.	Depth from Surface. Feet.
Surface-soil and wash	68	68
Ecca (Karroo) Series, with seams of coal ...	762	830
Dwyka Conglomerate	15	845
Dolomite	2,925	3,770

This result confirms the view held by the writer that a syncline occurs in this neighbourhood, as shown on the plan.*

Mr. H. W. Struben (London) wrote that he had read Mr. Sawyer's paper with great interest, together with the plans and sections showing the work that Mr. Sawyer had done during the last four years on a section of country hitherto undeveloped and which he sincerely hoped, in the interests of South Africa, would prove a second Witwatersrand. It seemed an age since, in June, 1885, he (Mr. Struben) made known to his Honour, the late President Kruger, his Executive Council, and the assembled Volksraad, the discovery of 42 miles of gold-bearing conglomerate-beds along the watershed of the Witwatersrand, where his brother, himself and their employees had worked on the wild, open veldt, living in waggons and tents, where now thousands of houses, batteries, plantations, etc., cover the entire area, worldwide known as "The Rand." He was told by friends that he was a visionary, and would ruin himself. All the work was done at his own cost and risk, as not being an expert he would not take the responsibility of investing other people's money in an unproven venture. He would not dwell now on the discovery of the Rand, the absence of any reliable data, the anxious times, the successes and failures of the earlier days of the Rand; but he would draw attention to the fact that Mr. Sawyer, with his knowledge of geology and mineralogy, and the now known conditions in the mines at a depth on the central Main Reef series, had definite information, of which he (Mr. Struben), in 1885-1886, had no conception, and he trusted that Mr. Sawyer's industry and perseverance would meet with as great a measure of

* *Trans. Inst. M. E.*, 1904, vol. xxvii., page 554, plate xxv., fig. 1.

success as crowned his own efforts on the northern edge of this extensive gold-bearing area. He and his brother, Mr. F. Struben, had to trace the pebble-reefs by outcrops and probe intermediate buried sections by sinking shafts; while Mr. Sawyer could work upon more or less ascertained lines, and form correct deductions based on practical experience. If the results of further development proved as satisfactory as the data submitted would lead one to hope, this discovery of a section of gold-bearing country, 50 miles south of the northern outcrop, and corresponding in formation to the Main Reef series, would give fresh impetus to the mining industries of the Transvaal and Orangia. In 1885, the existence of the most continuous and permanent gold-mining area in the world was unknown, but energy, capital and foresight had combined to produce gold worth many millions. He was confident that the potential wealth of these South African uplands was not yet realized, systematic prospecting should still be continued, for so far the country had merely been scratched, and only a commencement had been made in the development of its vast mineral resources. On June 6th, 1885, he (Mr. Struben) sent for the first stamp-battery as a testing-mill; and now thousands of stamps thunder day and night along miles of what was then bare veldt worth a few shillings per acre. On December 20th, 1885, the first conglomerates were crushed, and since then gold valued at millions of pounds sterling had been obtained from the tilted pebble-beds. There was evidence that these conglomerates, auriferous in greater or less degree in various sections as they traversed the country from west to east, were practically continuous for hundreds of miles, confirming the opinion held by him in 1885-1886 that they were formed on the coast-line of Southern Africa, many geological ages ago; and Mr. Sawyer's recent discovery, at the junction of the Wilge and Vaal rivers in the Orange River Colony, fully established that theory. These conglomerate gold-fields were continuous, and with the exception of certain sections along the line of reefs were not rich, when compared with the gold found in erratic quartz-reefs in other countries; consequently the strictest economy was necessary if they were to be worked to profit.

Over fifty years' experience in Natal and in the Transvaal, in official and private capacities, and in conducting industrial operations, had convinced him that native African races (Zulu, Basuto,

Bechuana, etc.) were incapable of continuous labour, especially arduous labour such as mining; and it was obvious that no considerable industry could be carried on successfully without continuity of labour.

The mining industry required greater facilities for the conveyance of unskilled labour from a distance to the mines, as natives only worked for a short time and must frequently be replaced. It should be remembered also that the increasing agricultural development of the country demanded a considerable share of the available labour-supply, and that about six men per annum were required to perform one man's work, as the average time that a native cared to work continuously on a farm was about two months. The future prosperity of South Africa would largely depend upon the discovery of some method that would induce natives, who were rapidly increasing in numbers, to work more continuously than they did at present. He feared that he had taken up much time in dealing with the native labour question, but the mining industry depended upon its satisfactory solution.

Mr. Sawyer, by his practical and exhaustive research, appeared to have discovered an extensive gold-area; its development would largely benefit the Orange River Colony and the Transvaal, and he cordially wished his enterprise every success. This and similar undertakings depended (1) on capital, and this could only be secured where confidence was established; and (2) on labour, continuous and at a reasonable cost. All else was at hand, in a perfect climate, that made mining a pleasanter occupation than in most other parts of the world. Personally, he had for many years taken no active part in mining matters; but he was confident that the time was near at hand when the real value of temperate South Africa as an important and highly mineralized country would be recognized, if not by people in Great Britain, then by others.

Mr. G. A. Denny (London) wrote that he had very grave doubts whether capital for the deep-level areas of the Witwatersrand would ever be raised; and, if it should be raised, whether there would be any commercial profit arising out of it, unless the capital-amount required for exploitation could be materially reduced; and, therefore, it might be inferred that his views regard-

ing the practicability of working an area situated 50 miles to the south of the Witwatersrand were not favourable.

Mr. SAWYER wrote, in reply to Mr. Denny, that as the Witwatersrand beds in the New Rand Gold-field dipped at an angle of 30 degrees it was obvious that the sub-outcrops of any auriferous "banket" interbedded among them would occur there at a vertical depth from the surface of from 670 feet to 700 feet, whatever the depth might be at which it might be intersected in any of the bore-holes. He could not, therefore, see that Mr. Denny's remarks were applicable to sub-outcrop propositions on the New Rand Gold-field. He failed to see what connection there was between the difficult deep-level propositions on the Witwatersrand, with their working depths of from 2,000 feet to over 4,000 feet, and possible sub-outcrop propositions in the New Rand of from only 700 feet to, say, 1,500 feet.

The PRESIDENT (Mr. M. Deacon) moved a vote of thanks to Mr. Sawyer for his interesting paper.

Mr. W. G. PHILLIPS seconded the resolution, which was cordially approved.

Mr. D. M. CHAMBERS' paper on "The Ozokerite (Mineral-wax) Mine of the Galizische Kreditbank, at Boryslaw, Galicia, Austria," was read as follows:—

THE OZOKERITE (MINERAL-WAX) MINE OF THE GALIZISCHE KREDITBANK, AT BORYSLAW, GALICIA, AUSTRIA.

By D. M. CHAMBERS.

Introduction.—Galicia, a Crownland of the Austro-Hungarian empire, is notably rich in supplies of liquid hydro-carbon. Some idea of the magnitude of the Galician petroleum-industry may be obtained from the fact that the crude-oil production for the year 1903 from Galicia alone was about 50 per cent. in excess of the quantity necessary to supply the whole illuminating-oil requirements for the Austro-Hungarian empire.

Closely allied to this industry, but much less well known, is the business of wax-mining. The product won, known as ozokerite, when purified, is largely employed in the manufacture of candles, and mixed with rubber, for insulating purposes, Great Britain being, perhaps, the best market for Galician ozokerite. Wax-deposits are fairly often met with throughout the country, but those of Boryslaw, Dzwiniacz, Starunia and Truskawiec are the best known; and although all are worked to a greater or less extent, the deposits of Boryslaw, a village about 75 miles south-west of Lemberg, the capital of the province, are by far the most important. The existence of ozokerite at Boryslaw has been known for very many years; in fact, the workings date back to the year 1831. Nevertheless, the systematic exploitation of the mines only commenced after 1880, and by far the best-equipped mine at the present day is that belonging to the Galizische Kreditbank. This company acquired the workings of various small owners, consisting of about seventy to eighty separate shafts, sunk to depths of up to 200 feet and more in certain cases.

The early history of the company was unfortunate, owing chiefly to the fact that the work was carried on without any due regard to the rudiments of mining technology, and it was only at

the end of 1898 that the installation of the present admirably-arranged system of working was commenced, since which time matters have improved out of all recognition.

Geology.—According to Dr. Joseph Muck,* the geological formation of that part of Boryslaw from which both ozokerite and petroleum are obtained is properly classified as belonging to the Miocene series of the Tertiary System. The formation consists of alternating layers of grey sandstone (rich in muscovite) and grey shale: the strata being much disturbed. The sandstone is frequently very porous, impregnated with bitumens, and of a brown colour, and is then locally known as *Sytitica* stone. The shales are generally very hard and impervious, but always laminated and so disturbed that it is sometimes extremely difficult to form any correct opinion as to the run of the strata. Layers of rock-salt are frequently found, and sometimes veins of gypsum. The whole formation is poor in fossils. Gas is present in large quantities in the workings, and petroleum is also frequently met with in the wax-mines.

Surface-installation.—With the exception of the winding-engine at the main shaft, all power used throughout the mine for pumping, ventilation, hauling, etc., is electrical: the company generating its own energy. Steam is raised for this purpose in a battery of five tubular boilers of ordinary pattern, each with a heating-surface of 754 square feet (70 square metres), generating steam at a pressure of 10 atmospheres, and fired by gas obtained from the mines. Steam is led from the boiler-house direct to the electrical generating-house and the winding-engines. The boiler-house is a brick-and-timber structure; and water for the boilers is obtained from the river running near the property. The electrical power-house consists of a separate brick building, containing two sets of direct-coupled direct-current 77. kilowatts Siemens-and-Halske machines, both of which run at about 140 revolutions per minute. Each set is sufficient for supplying all necessary current for the mine at any time, and each set is run for a shift of 12 hours per day. A main switch-board of simple pattern controls the supply of current to all parts of the mine.

* *Der Erdwachsbergbau in Boryslaw.*

The compound winding-engine develops 240 horsepower. The steam-valves, brakes, reversing gear, etc., are placed so that the engineer, at his platform, has complete control over the whole engine; whilst the speed at which the cage is travelling, together with its position in the shaft, is shown by an arrangement of the usual kind. The cages, running in guides, are used for the drawing of material, and for conveying men into and from the workings. The winding-plant will deal with a daily production of about 850 tons, corresponding to a monthly output of 180 to 200 tons of wax.

Mines.—The workings are entered by a main shaft, sunk to a depth of 738 feet (225 metres), with a diameter of about 13 feet (4 metres). The shaft, for a depth of 89 feet (27 metres) from the surface, is lined with masonry to keep out surface-water; and the rest of the shaft is very heavily timbered. In addition to this main shaft, a smaller one for conveying material only is situated at the far end of the workings. From the main shaft, two main levels run, one at 410 feet (125 metres) and the other at 738 feet (225 metres); and there is an intermediate level between them, at a depth of 574 feet (175 metres), not connected to the main shaft, but it is connected with the other two levels by a staple, fitted with an electric winding-plant for the conveyance of materials.

Galleries, driven from the levels, follow the wax in all directions. They are heavily timbered, owing to the extremely unstable nature of the formation in which the wax is found: indeed, so great is the pressure on the timbering on all sides that solid pieces of hard beech (the wood ordinarily used), 12 to 15 inches thick, are bent out of shape, and frequently snapped in a few days; and a large staff of men is continually employed in attending to the timbering throughout the mine. A curious effect of the instability of the formation is to twist even short shafts out of shape. Mounting such a deformed shaft can only be likened to climbing a spiral ladder. From all sides of the galleries, headings are driven following the wax-veins until they are lost.

The galleries are provided with tramways for the transit of small four-wheeled trucks pushed by hand. Each cage lifts three trucks at a time.

Owing to the large amount of gas always present, ventilation

has to be most carefully attended to. This is generally done by means of doors and heavy brattice-curtains, and electric blowing-fans are always at work forcing air to the extreme end of the various headings. Sometimes in new workings, primitive hand-blowers are still met with, worked by boys. As a general rule, the greatest quantities of gas are found in the deepest workings. Safety-lamps are used for lighting purposes practically throughout the entire mine, and only in the neighbourhood of the main shaft has electric lighting been installed. In spite of all precautions, explosions are of not infrequent occurrence. A great feature of the lower workings is their extreme dryness, as opposed to the large quantities of water mixed with some oil found at the higher levels.

An extensive pumping installation is provided on the higher level, in close proximity to the main shaft. In a large chamber, cut out of the rock and lined with bricks, there are four electrically-driven pumps capable of raising together 396 gallons (1,800 litres) per minute. All the water found in the workings is conveyed by pipes to a large reservoir under the floor of the pump-room, whence it is lifted to the surface.

Treatment of Wax.—The wax, won from the mine, varies largely as regards purity. In many cases, especially in new workings, the wax is found in a more or less pure state, and very little treatment is necessary to prepare this variety for the market. The trucks bringing it to the surface are run to a special receiving-shed where girls subject it to hand-picking, after which it is melted, the impurities rise to the surface and are skimmed off, and the pure wax remaining is run out and cast into moulds and is ready for the market.

Usually, the wax is more or less intimately mixed with rock and shale, and has to be subjected to a more complicated course of treatment before it can be put on the market. The trucks bringing it to the surface are run along a set of elevated rails to the second floor of a building, where the trucks are tipped and the contents spread on tables on the first floor. Here girls immediately hand-sort it, and are sufficiently experienced to determine the stone without wax from that containing wax at a glance. The former is at once cast away, but the wax-stone is cast into a hopper, whence it runs to trucks on the ground-floor ready to

receive it. As a general rule, the stone contains only about 1 per cent. of wax, consequently it is evident how much work has to be done before any considerable quantity of wax is obtained.

The sorted stone is wheeled away to the washing shed, where it is cast into large circular boilers, not unlike washing coppers, mixed with water and cooked. The wax is melted out of the stone and rises to the surface of the water, where it is skimmed off and put into receptacles. The skimming process is continued until wax ceases to come to the surface, when the water, stone and dirt are cast away, and a fresh charge put into the boilers.

The wax thus obtained is melted a second time, but without water. The impurities rise to the surface and are skimmed off; whereupon the residue is run into moulds, cooled, and is then ready for the market.

Different grades of refined wax are put on the market, but the above gives a general idea of the various processes to which it is subjected. The treatment varies according to the purity or otherwise of the wax, more than one washing often being necessary. The tailings are separately treated, so as to recover any wax that may have passed unnoticed through previous treatments.

At the end of the year 1903, when the writer visited the mines, the wax realized £79 to £80 per ton and cost £41 to £42 per ton to mine and refine. The vend is closely regulated, and in 1903 this mine marketed from 100 to 120 tons monthly.

The PRESIDENT (Mr. M. Deacon) moved a vote of thanks to Mr. Chambers for his interesting paper.

Mr. M. WALTON BROWN seconded the resolution, which was cordially approved.

Dr. C. SANDBERG's "Notes on the Structural Geology of South Africa" were read as follows:—

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means of doors and heavy brattice-curtains, and elect
fans are always at work forcing air to the extrem
various headings. Sometimes in new workings,
blowers are still met with, worked by boys.
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be drawn regarding the origin of the geological
outh Africa, as one indivisible edifice; and this
may be considered as an attempt in that direction.

II.—Main Direction of Mountain or Fold-producing Pressures.

(a) South-to-north Pressure.—Dr. G. A. F. Molengraaff states, referring to his South African Primary system, that the strata were nearly everywhere greatly tilted, folded and dislocated; and that these movements of dislocation had been the result of mountain-forming forces which had been exerted generally from south to north.* This view is also held by Prof. H. G. Seeley.†

* "Géologie de la République Sud-Africaine du Transvaal," by Dr. G. A. F. Molengraaff, *Bulletin de la Société Géologique de France*, 1901, fourth series, vol. i., pages 18 and 19.

† "Some Scientific Results of a Mission to South Africa," by Prof. H. G. Seeley, *Transactions of the South African Philosophical Society*, 1889, vol. vi., page 1.

NOTES ON THE STRUCTURAL GEOLOGY OF SOUTH AFRICA.

By C. SANDBERG.

I.—Introduction.

With the increase of knowledge of the geology of South Africa, it will prove to be less and less satisfactory to invoke the influence of comparatively small and very restricted forces, in order to explain the cause of folding and tilting in the different sedimentary systems. The tectonic characteristics of different regions, hitherto often regarded and studied as the result of local and separate phenomena, as, for instance, huge igneous intrusions here, faults in another region, etc., will, as a wider view is taken, more and more prove to be unmistakably connected with one another in origin. Once this conclusion is accepted, one may hope to ascertain the law or laws which governed the energies that built up the geological structure at the time or times of their action. Although the data already accumulated by various authors do not cover every portion of the region, the writer thinks that even now, certain general conclusions might be drawn regarding the origin of the geological structure of South Africa, as one indivisible edifice; and this paper may be considered as an attempt in that direction.

II.—Main Direction of Mountain or Fold-producing Pressures.

(*a*) *South-to-north Pressure.*—Dr. G. A. F. Molengraaff states, referring to his South African Primary system, that the strata were nearly everywhere greatly tilted, folded and dislocated; and that these movements of dislocation had been the result of mountain-forming forces which had been exerted generally from south to north.* This view is also held by Prof. H. G. Seeley.†

* "Géologie de la République Sud-Africaine du Transvaal," by Dr. G. A. F. Molengraaff, *Bulletin de la Société Géologique de France*, 1901, fourth series, vol. i., pages 18 and 19.

† "Some Scientific Results of a Mission to South Africa," by Prof. H. G. Seeley, *Transactions of the South African Philosophical Society*, 1889, vol. vi., page 1.

Dr. Molengraaff also states that this rule has many exceptions,* but he has only tendered an explanation of one of these exceptions in his paper on the Vredefort Mountain-land, when he says that "we should fail to find that the overtilting [of the older sedimentary strata round the Vredefort batholite] is due to lateral pressure, as is shown to be the case with the great majority of the large mountain-chains; . . . . In our area there is no sign of unilaterality in the structure; . . . . evidently, the pressure has been exerted in every instance from the centre towards the periphery."† Dr. Molengraaff had admitted that the whole of the sedimentary deposits from his Primary system, up to and including the Transvaal system, had been simultaneously affected by the same cause.‡

Mr. E. Jorissen has emphasized his opinion of the mountain or fold-producing pressure having had a direction from north to south, that was, diametrically opposed to the one assumed by Dr. Molengraaff.§

Mr. A. R. Sawyer was of opinion that the African continent was formed by compressing forces, active during different ages, and having a south-and-east direction.‖

Speaking more especially of the Transvaal, the writer agreed with Dr. Molengraaff that it would often seem very difficult, if not impossible, to force field-evidence into the harness of the theory admitting only one exclusively south-to-north directed mountain-producing pressure; or any other pressure unilaterally directed. The writer could, on such a basis, never explain the perfectly tangential strike of the strata (around the periphery of a granite-mass) when the granite was surrounded by schists and other sedimentary beds, to which Dr. Molengraaff called special attention, magnificent demonstrations whereof are found round the Vredefort and Barberton granite-masses, and distinct tenden-

* "Géologie de la République Sud-Africaine du Transvaal," by Dr. G. A. F. Molengraaff, *Bulletin de la Société Géologique de France*, 1901, fourth series, vol. i., page 19.

† "Remarks on the Vredefort Mountain-land," by Dr. G. A. F. Molengraaff, *Transactions of the Geological Society of South Africa*, 1903, vol. vi., page 24.

‡ *Ibid.*, page 25.

§ "Structural and Stratigraphical Notes on the Klerksdorp District, with Special Reference to the Unconformity beneath the Elsburg Series," by Mr. E. Jorissen, *Transactions of the Geological Society of South Africa*, 1906, vol. ix., page 45.

‖ "Anniversary Address," by the President (Mr. A. R. Sawyer), *Proceedings of the Geological Society of South Africa*, 1905, pages xvi. and xvii.

cies to which are encountered again east of the Heidelberg and north, south and west of the Johannesburg granite-boss.

The explanation of its being due, in the case of the Vredefort granite-mass, to pressures having been exerted in every instance from a centre towards the periphery would seem, however, an hypothesis in contradiction with field-evidence. For, were it correct, why then should the effect of this pressure be found, as exhibited by the behaviour of the sedimentary beds, to have reached its maximum in a zone some distance away from the contact, as Dr. Molengraaff has pointed out? But what seems to be conclusive is that the least sign of rents, fractures or breaks is not found in these strata, and such should have been as the consequence of so violent an eruptive action. On the contrary, as will be shown later, these strata show distinct and unmistakable proof of having been subjected to strong compression.

Of the folding, tilting, etc., in the younger series, Dr. Molengraaff explains such as are evident around the Bushveld area, as having been the result of tensions called forth by the intrusion and subsequent substance of the Bushveld laccolite.* The writer will discuss the behaviour of these sedimentary strata hereafter, and will only now remark that the conception of the Bushveld granite-area as a laccolite is entirely of a hypothetical nature, and apt to be considerably modified as the knowledge of that area increases.

(*b*) *North-to-south Pressure.*—The extremely tilted nature of the sedimentary beds to the north of the Vredefort granite-boss may certainly be taken as pointing to an orogenic force, having worked from the north directly toward the south, as maintained by Mr. Jorissen. Sedimentary rocks impelled in a southerly direction under the influence of this force would, however, in encountering the Vredefort granite-boss supposing it to have been pre-existent), have been cleaved by the tearing and renting phenomena, attendant on the presence of this obstruction. Their dip would also differ at every point, in direct relation to the angle between the direction of the force and the tangential line at the periphery of the semicircle, at the point where the line representing the force meets that periphery. It is clear from

* "Géologie de la République Sud-Africaine du Transvaal," by Dr. G. A. F. Molengraaff, *Bulletin de la Société Géologique de France*, 1901, fourth series, vol. i., page 56.

fig. 2, that the intensity of the radial force, *bc*, plying the sedimentary beds round the granite-boss, and at the same time determining their strike and dip, diminishes from a maximum at the extreme north, to nil at 90 degrees from it to the east and west, and the inclination of the strata towards the granite-boss would thus proportionally decrease from a maximum at A to nothing at B.* As the strike of the strata at the north, west and east of the Vredefort granite-mass remains tangential to its periphery, and as their dip remains equally similar throughout, this assumption must also be discarded as impossible. The same reasoning applies equally to the Barberton and other supposed pre-existing granite-bosses showing similar conditions, and excludes the possibility of these sedimentary beds having been under the influence of any unilateral force during the mountain-folding period or periods. Further, the upward and downward curving of the anticlinal and synclinal axes of the folds striking east and west, so apparent on Dr. Hatch's map of the southern Transvaal,† could not have been engendered by any unilateral force, nor could even the brachy-synclinal which Mr. Jorissen may justly claim the merit of having discovered at Rietkuil.‡ A similar reasoning, as regards the granite-masses, is applicable to prove that the assumption of two folding forces (south and east)§ could not explain the phenomena above described.

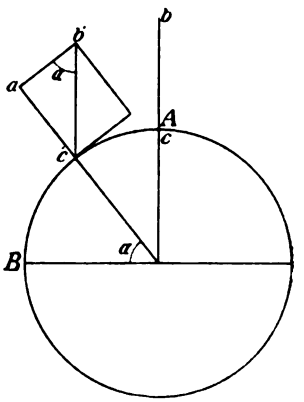

FIG. 2.—NORTH-TO-SOUTH PRESSURE.

(*c*) *Omni-lateral Pressure.*—To account for this homogeneous encircling of the granite-bosses by the sedimentary masses in the way referred to above, one is bound to admit that they

* *Trans. Inst. M. E.*, 1907, vol. xxxiii., page 548.

† *A Geological Map of the Southern Transvaal*, by Dr. F. H. Hatch, London, 1897; second (revised) edition, London, 1904.

‡ "Structural and Stratigraphical Notes on the Klerksdorp District, with Special Reference to the Unconformity beneath the Elsburg Series," by Mr. E. Jorissen, *Transactions of the Geological Society of South Africa*, 1906, vol. ix., page 46.

§ "Anniversary Address," by The President (Mr. A. R. Sawyer), *Proceedings of the Geological Society of South Africa*, 1905, pages xvi. and xvii.

were subjected to simultaneous pressures, which could all be reduced for convenience sake to four main pressures directed to one common centre and of 90 degrees between each (fig. 3, *a*, *b*, *c* and *d*). Locally three of these forces must have been, roughly speaking, of equal value; in the case of the Vredefort area, *a*, *b* and *d*; and in the case of the Barberton area, *a*, *c* and *b*. Of course, one or more will generally predominate over the others, a predominance which is expressed in the behaviour of the folds and, for minor accidents, is often still traceable to local and secondary causes.

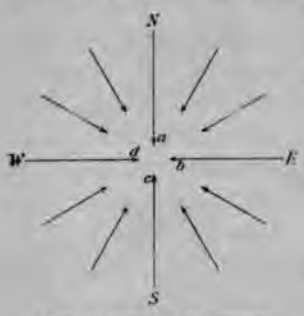

FIG. 3.—OMNI-LATERAL PRESSURE.

The question now arises whether one is entitled to generalize the conclusions arrived at by the study of these granite-masses and to conclude that this system of forces has exercised its influence over the whole of South Africa; and the fact that evidence of their action, as described above, is to be found scattered all over the central part of the Continent certainly points in this direction. Now, if similar evidence could be shown to exist in other parts of South Africa, then the writer thinks that such a generalization could be enunciated.

On reference to a geological map of South Africa (fig. 1, plate xxi.), a prominent feature is seen at once, and very forcibly, namely, that in the central zone of South Africa, the strike of the folds, that is, the direction of their axes, runs east and west. Detailed mapping on a much larger scale has only emphasized this feature, showing the deviations from this course to be purely local as a rule, and proving a distinct tendency to return to the main east-and-west direction. This can be seen in the southern part of Cape Colony, in the endless flats of the Karroo, and in the Orange River Colony; it is found in the Central Rand, in the Rustenburg-Pretoria-Middelburg area, in the Bushveld, as well as in the Chuniespoort, the Pietersburg and the Leydsdorp districts, and further north. Everywhere, the beds of all the sedimentary systems, if folded at all, from Swaziland to the Upper Karroo, show that the axes of their folds extend east and west.

These facts, being so general over the whole central zone of

South Africa, from its southern shore to the north of the Transvaal, exclude the possibility of their having been brought about separately, by local and comparatively insignificant causes. They give the author the right to generalize and to conclude that the north-and-south directed energies, the action of which left such unmistakable proofs on the strata round the granite-masses, have been at work over the whole of this part of South Africa, affecting all the above-mentioned sedimentary systems. The comparative value of these two opposing forces (north to south and south to north) has, of course, been different over every area, the northward pressure generally predominating.

Dr. G. A. F. Molengraaff's map of the Transvaal* shows that, on the eastern border of the Highveld, the strike of the axes of the folds is north and south, in the Lydenburg, Machadodorp and Barberton districts. The subsidence of the Bushveld laccolite is assumed partly to explain this north-and-south course, but its persistence beyond the range of influence of so small an accident justifies one in looking for other causes which might have produced these phenomena. Southward of Barberton, the disposition of the strata becomes much flatter, so that it is often very difficult to recognize a strike-direction in the overlying younger series. In the Vryheid district, a tendency towards this north-and-south direction of strike is distinctly noticeable, even in the younger series,† whilst Mr. C. L. Griesbach, in his map and section, discloses an identical disposition existing in Natal.‡ Speaking of the older formations, he stated that "all these slate formations [mica-schists, clay-, chlorite- and talcose-slate formations] are to be met with at places where the granite base is laid bare; and everywhere the slates stand nearly upright, at an angle of 70 to 75 degrees, with a strike from north to south."§ He then quoted different localities all over Natal, remarking that these granite-masses are situated in a straight line

* "Géologie de la République Sud-Africaine du Transvaal," by Dr. G. A. F. Molengraaff, *Bulletin de la Société Géologique de France*, 1901, fourth series, vol. i., page 92, plate i.

† Mr. D. Draper found the Karroo series to the south of the Umkusi river, showing steep dips to the west and to the east.

‡ "On the Geology of Natal, in South Africa," by Mr. Charles Ludolf Griesbach, *The Quarterly Journal of the Geological Society of London*, 1871, vol. xxvii., page 72, plate ii.

§ *Ibid.*, page 55.

from the Umtwalume river due north. Similar conditions prevail, it would seem, in Pondoland, right down to Port St. John on the Indian Ocean.

In the Lydenburg district, Mr. A. L. Hall* has substantially confirmed Dr. Molengraaff's mapping. The axes of the folds in the older beds (Transvaal system) have a distinct north-and-south orientation: the same tendency being unmistakably shown in the behaviour of the gently-inclined younger series.

Further east and south, Mr. H. Kynaston's investigations† have led to important results. He has established the fact that there is no sign whatever of the great north-and-south fault in the Komatipoort district, which was supposed to exist west of and parallel to the Lebombo range. Neither has Mr. W. Anderson,‡ either in Zululand or in Natal, found any trace of this supposed fault, his conclusion being as equally emphatic as to its non-existence here, as Mr. Kynaston's was as to its absence further north.

The strike, dip, constitution and general behaviour of the sedimentary series remaining the same for more than a 100 miles to the north and south of the Komati river, together with Mr. Anderson's observations, lead to the conclusion that there is no great eastern fault south of the Singwedsi river. Consequently, the inclination of the strata of the Karroo system in this zone, which is generally one of from 15 to 25 degrees to the east, cannot be ascribed as having been caused by a downthrow fault. At the same time, it must be admitted that here again, as in the Lydenburg-Barberton-Vryheid area, this tilting is the result of the mountain-folding forces having had an east-and-west direction. Lastly, the form and structure of the lakes along the Zululand coast distinctly point to the same conclusion.

As for north-and-south pressure, there is ample evidence of its minor action here, as well as all over the Lydenburg-Machadodorp-Barberton-Vryheid-Natal area. The connexion of the north-and-south and east-and-west fold being further south,

* On the Geology of the Country between Lydenburg and the Devil's Kantoor," by Mr. A. L. Hall, *Transvaal Mines Department: Report of the Geological Survey for the Year 1905*, pages 39 to 57, plates ii., viii., xxii. and xxiii., and a map.

† "Report on a Survey of the Komati Poort Coal-field," by Mr. H. Kynaston, *Transvaal Mines Department: Report of the Geological Survey for the Year 1905*, pages 17 to 26, plate and a map.

‡ Personal communication to the author.

mainly hidden from view by the Indian ocean, the writer will now examine the western border of the South African continent.

Striking evidence of the action of the four main forces is to be found between Worcester and Van Rhynsdorp, on glancing at the geological maps of the south-west of the Cape Colony.*

Messrs. A. W. Rogers and A. L. du Toit testify to their having existed when they state that "the southern boundary-folds were produced by a force acting in a north-and-south direction, and the western ones by an east-and-west force. The two groups of folds meet in the neighbourhood of Karroopoort, and a complicated structure is the result."†

Then, again, in his description of the north-western part of the Van Rhynsdorp district, Mr. A. W. Rogers‡ recognized a great pressure as having exerted its influence from the west; the general strike is consequently one tending towards the north, the dip being towards the west. The north-and-south pressure has here again left abundant evidence of its minor action.

In Damaraland, constituted mainly (as it would seem) of the older deposits, the strike of the strata is again east-and-west, coinciding with the direction prevailing in the central zone of South Africa.

In German South-West Africa, evidence of the combined action of these forces is again available, the strike of the country being, according to Dr. F. W. Voit,§ north-east and south-west, while lower down in Griqualand West, the strike affects a north-east and south-west direction, changing to north and south mainly in British Bechuanaland. Here, however, it is often difficult to speak of a general strike.‖

In Rhodesia, the north-and-south and east-and-west trend of

* *Second Report of the Geological Survey of Natal and Zululand*, by Mr. William Anderson, 1904.

† "Geological Survey of Parts of the Divisions of Ceres, Sutherland and Calvinia," by Messrs. A. W. Rogers and A. L. du Toit, *Cape of Good Hope: Department of Agriculture:* [*Eighth*] *Annual Report of the Geological Commission, 1903*, page 13.

‡ "Geological Survey of the North-western part of Van Rhyn's Dorp," by Mr. A. W. Rogers, *Cape of Good Hope: Department of Agriculture: Ninth Annual Report of the Geological Commission, 1904*, page 14.

§ "Beiträge zur Geologie der Kupfererzgebiete in Deutsch S.W. Afrika," by Dr. F. W. Voit, *Jahrbuch der Königlich Preussischen Geologischen Landesanstalt und Bergakademie zu Berlin für das Jahr 1904*, vol. xxv., page 384.

‖ Private communication to the author from Mr. A. L. du Toit.

the strata in different areas make it probable that the same causes have been at work there.

FIG. 4.—QUARTZITE, NORTH OF THE VREDEFORT GRANITE-MASS, AASVOGELRAND, SHOWING THE VERTICAL JOINT-PLANES.

In the Central zone, where the preponderance of north-and-south forces is seen, evidence of the action of the east-and-west forces is testified to in a remarkable degree by the upward and downward curving of the axes of the folds, which in the Witwatersrand is so evident from Dr. Hatch's map.* A similar convincing proof is recorded by the highly-tilted quartzites at the northern periphery of the Vredefort granite-mass on the Aasvogelrand, Orange River Colony, vertical joint-planes running north and south being magnificently developed therein, as shown in fig. 4. Their very presence and development prove that these strata had been subjected to considerable pressure from the east and the west.† The effect of this pressure on the axes of the folds is not observable here, the strata being too much tilted.

* *A Geological Map of the Southern Transvaal*, by Dr. F. H. Hatch, London, 1897 ; second (revised) edition, London, 1904.

† *Trans. Inst. M. E.*, 1907, vol. xxxiii., page 543.

The writer may mention that he is very much inclined to regard the Vredefort granite-mass as a denuded dome, being part of a fold, the axis of which may perhaps be roughly parallel to the Klerksdorp-Johannesburg-Heidelberg fold, and marked by their three denuded granite-masses on Dr. Hatch's map of the Southern Transvaal.*

From the above facts, the writer may conclude that the whole of the South-African sub-continent has been subjected, during one or more periods, to mountain-folding pressures, mainly directed in a north-and-south and an east-and-west direction; the result of the former being predominantly evident in the Central zone, and that of the latter on the periphery of South Africa. The variations of strike and dip in the sedimentary strata, so conspicuous in south-western Cape Colony, round the granite-masses, in the Witwatersrand area, in the Rustenberg-Middelburg area,† round the Bushveld laccolite, etc., may thus be readily explained as the result of the action of these pressures.

III.—Origin of Poorten,‡ River-valleys and Pans.§

(*a*) *Poorten and River-valleys.*—When making a trip along the broad valley following the southern escarpment of the Magaliesberg range (north of Pretoria) (or for the matter of that either of the two parallel inner ranges) it is seen to be broken through by gaps, called poorten.

Dr. G. A. F. Molengraaff, on different occasions, has explained the origin of poorten as due to tensions called forth by complex movements caused by the subsidence of the strata of the Transvaal system under the weight of the Bushveld igneous masses accumulated above them, during the period of their intrusion. He (Dr. Molengraaff) states that "these complex

* *A Geological Map of the Southern Transvaal*, by Dr. F. H. Hatch, London, 1897; second (revised) edition, London, 1904.

† "On Folding and Faulting in the Pretoria Series and the Dolomite," by Messrs. A. L. Hall and F. A. Steart: Mr. A. L. Hall's reply to the discussion, *Proceedings of the Geological Society of South Africa*, 1905, page xliii.

‡ *Poorten* (plural of *poort* or porch in English) is the name given by the Boers to gaps in mountain-ranges, and now in universal use throughout South Africa. It is pronounced poart.

§ *Pans* (plural of *pan* or pan in English) is the name given by the Boers to shallow depressions (circular, oblong or kidney-shaped) containing water, at least in the rainy season, and sometimes the whole year through. It is similar to the *bassins fermés* of French and Swiss geologists.

movements have given rise to tensions which, in the outer range of the curve, the Magaliesberg range, necessitated an extension in length; consequently the Magaliesberg range was fractured, and the rents so caused have originated the natural gorges called by the Boers *poorten*, . . . Generally these crevices are filled with eruptive matter."* American geologists have explained their origin by the shifting of the drainage-lines.

Messrs. A. L. Hall and F. A. Steart, in the beginning of 1906, stated that "to find an eruptive breccia in a poort is rather an exception than a rule."† Subsequently the work of the Geological Survey has shown that this exception is very rare, and, moreover, that the continuation of the strata in these poorten is, so to say, never interrupted. These same facts can be observed all over the South African continent, and in the deposits of every one of our sedimentary series, as is quite evident in the field, as well as from a study of the geological maps of the Transvaal, the Cape Colony and Natal.

This then would have been sufficient to do away with the "rent" theory (based on exceptional and local evidence within a small area as it would seem) as a probable explanation for the origin of these gaps. But when this range is examined where these rents should have been best developed, everywhere distinct evidence of compression is found instead of stretching. Following, for instance, the uppermost quartzite-beds in any of these ranges, it will be seen that, on nearing a poort, they bend down gradually, become flatter towards the centre, and rise up again on the other side of the poort to form the capping of the ranges again. As there is no discontinuity of the strata, this phenomenon cannot be ascribed to faulting, and it must be acknowledged to be due simply to the downward curving of the axes of the fold. The entrance of the Zwartebergen-poort (fig. 5) in Cape Colony is very clear evidence on the subject. This undulation in the axes of the folds is simply due to the east-and-west pressure referred to above, the existence of which in the past has been shown to be manifest over the whole of South Africa, and the proof of this contention is found at the summit of the same Magalies-

* *Geology of the Transvaal*, by Dr. G. A. F. Molengraaff, translated from the French by Mr. J. H. Ronaldson, 1904, page 55.

† "On Folding and Faulting in the Pretoria Series and the Dolomite," by Messrs. A. L. Hall and F. A. Steart: Mr. A. L. Hall's reply to the discussion, *Proceedings of the Geological Society of South Africa*, 1905, page xliii.

berg range, as well as in the poorten. Last year, the writer had occasion to draw the attention of one of his colleagues to this fact, which is demonstrated by the presence of vertical pressure-planes and of superimposed monticules on the top of the range, that is, between Wonderboompoort and Crocodilpoort, where these vertical joint-planes are seen running north and south. A typical example of these monticules can be easily reached and studied, standing as it does in the centre of one of these very poorten, in Commandonek.

FIG. 5.—ENTRANCE TO THE TYGERBERGPOORT, NEAR PRINCE ALBERT, CAPE COLONY, SHOWING THE INCLINATION OF THE STRATA, TOWARDS THE CENTRAL PORTION OF THE POORT.

In the two inner parallel ranges, nearer the Johannesburg granite-mass, these facts may perhaps not be so apparent, as the local augmentation of the intensity of the compressing forces has engendered complicated structures, whilst erosion has also often obscured the facts. But even here, with a little trouble, the problem can generally be disentangled, and its origin traced to the influence exercised on the strata by these mountain-folding pressures.

The same evidence is available in the Witwatersrand area, and further south in the Karroo and other parts of the Cape Colony, Natal, etc., and in all the systems from the Witwatersrand upwards.

The writer will now describe the peculiar structure of the Alps. From Genoa, this chain bends round in a graceful polygon to Bâle; thence to Innsbrück and further east, the angles between the strikes of the strata are less pronounced. The central part is occupied by the huge gneiss and granite-masses of Mont-Blanc, Dent Blanche, Weisshorn, Ofenhorn, Monte Rosa, P. Pombi, and P. Stella, Borgasesia, Omegna, etc. The whole structure of the chain seems to prove that this magnificent erection has been built up by the action of forces emerging and radiating from one common igneous centre. Here, far more than in the Rustenburg-Middelburg and Vredefort areas, the idea is forced upon us that the sedimentary strata have been subjected to enormous pressure from within, and consequently to stretching tensions. This impression is strengthened almost to conviction when by closer study it is observed that all the rivers break away from the chain in a radial fashion, and, moreover, at the very point where the strike of the strata change in direction. Dr. M. Lugeon conclusively proved,* however, not only that the curious valley of the Rhone (between Martigny and the Geneva lake), as well as the great majority of the Alpine valleys, were due to orogenic causes, but also that there was no sign of rents due to supposed bending and stretching tensions. He showed, moreover, that rivers generally follow the main and secondary synclinal troughs produced by and during the process of mountain-folding, and that they break away from the chain by outlets provided by the downward curving of the axes of the folds, producing poorten, due to forces directed at more or less high angles to the main fold-producing ones.

These facts are equally observable in the field, as on any detailed geological map on a large scale. And it appears self-evident that nature will rather make use, for its drainage-purposes, of the more or less large synclinal troughs readily provided by folding, than of the cracks and crevices which may

* "Recherches sur l'Origine des Vallées des Alpes Occidentales," by Dr. M. Lugeon, *Annales de Géographie*, 1901, vol. x., pages 295 to 317 and 401 to 428.

have been formed all along the top of anticlinal folds, and which would have to be dug out.

The only excuse for having so long adhered to the anticlinal crest-valley theory is perhaps that erosion has often hidden, even obliterated, the real facts, so that their origin have become nearly untraceable. Such may have been the case in the Jura, from where this theory originated, or at least received its strongest support.

(*b*) *Pans.*—Mr. M. S. Alison was the first who tendered a theory to explain the origin and formation of pans. He suggested their having "been excavated by the hoofs of animals collecting mud, while going from and returning to certain centres to quench their thirst."* It would appear that his very words imply the existence of a depression or basin previous to the arrival of those animals, and so his theory might, perhaps, well account for the enlarging and deepening-out of a pan, but hardly for its origin.

Dr. G. A. F. Molengraaff ascribed their origin to wind and chemical action chiefly,† and though this may undoubtedly have been the case in many instances, the question why the wind and the chemical agencies should have selected and belaboured the particular spot where the pan is found may often remain unanswered.

Prof. A. Prister considered their origin to be closely connected with the rock in which they occur. He had specially drawn attention to the fact that pans were generally found in gently undulating country, and that such undulations may form either a river-bed or a pan. Rainfall, evenly divided over the year, would produce the former phenomenon, while intermittent rainfall, variation of temperature, etc., would originate the latter.‡

Mr. E. T. Mellor ascribed the origin of some pans at least to the "removal of the pyritic and soluble portions of the strata affected, followed in some cases by subsidence of the overlying

* "On the 'Origin and Formation of Pans,'" by Mr. M. S. Alison, *Transactions of the Geological Society of South Africa*, 1898, vol. iv., pages 159 to 161.

† *Ibid.*, discussion, page 161.

‡ "Notes on Mr. Alison's paper 'On the Origin and Formation of Pans,'" by Prof. A. Prister, *Transactions of the Geological Society of South Africa*, 1899, vol. iv., pages 167 and 168.

beds."* He (Mr. Mellor) noticed that these curious basins "almost always occur either close to the head of a spruit or on the watershed between two or more spruits."†

Lastly, Mr. J. P. Johnson summed up his definite conclusions regarding their origin as follows:—(1) All pans are on the site of springs; (2) all pans are intimately connected with dykes; (3) these springs once came to the surface, and were the main factor in the formation of pans; (4) in many cases they still rise to within a short distance of the surface; and (5) these springs are due to the damming-back of underground water by dykes.‡ It is clear that some of Mr. Johnson's conclusions are perhaps to be regarded more as a necessary consequence of pan-formation than as the cause thereof. And as to his statement that all pans are intimately connected with dykes, the writer doubts whether many of the members would like to support it unconditionally.

Still, as nature did not work according to any one rule which might be imputed to her, the writer is convinced that the various explanations given above do rightly account in many instances for the formation of pans.

Prof. A. Prister stated that "pans generally belong to gently undulating country;"§ and Mr. E. T. Mellor, "close to the head of a spruit or on the watershed between two or more spruits."‖

In an intensely-folded country one of the orogenic forces will be largely preponderant and thus produce well-defined anticlines and synclines. In a softly undulating country, however, the intensity of the orogenic forces has evidently been small; the chances of the radial opposing main-forces being nearly equal, are thus much greater than in a more disturbed region. Brachy-synclines, basins, pans or domes, being the result of an approximate equality of these forces at a given point, will thus be readily met with in little-disturbed areas. The points where this con-

* "The Origin of 'Wash-outs' in Coal-mines and their Relation to other Features of the Transvaal Coal-measures," by Mr. Edward T. Mellor, *Transactions of the Geological Society of South Africa*, 1906, vol. ix., page 78.

† *Ibid.*, page 81.

‡ *Ibid.*, discussion, *Proceedings of the Geological Society of South Africa*, 1906, page xlix.

§ "Notes on Mr. Alison's paper 'On the Origin and Formation of Pans,'" by Prof. A. Prister, *Transactions of the Geological Society of South Africa*, 1899, vol. iv., page 167.

‖ *Op. cit.*, page 81.

dition of the approximate equality of the forces has the best chance to come about in more disturbed regions, are at a river-head and on a watershed, as the action of the predominating force here met with the greatest resistance: consequently these are the places where pans are most likely to be formed, again as a result of the action of orogenic forces.

If now in a gently undulating country a more resistant factor is met with in the strata, such as an igneous dyke (Mr. J. P. Johnson), basin-shaped accidents will by preference be formed all along it, on the same principle, as they will be most readily originated on a small scale, all along a more resistant zone in a thin indiarubber sheet which is being subjected to a centripetal lateral pressure. It also becomes very clear why springs should be found either close to or at the bottom of most of these pans, or only a few feet below them; especially in the Karroo formation, with its alternation of sandstone and shale. The atmospheric precipitations, falling on and saturating the top layers of some formation or other, will in their further, that is, descendent, course be deviated along the inclination of those strata. Their tendency is to collect in the natural basins and river-valleys, forming springs of more or less strong flow, according to the quantity of water absorbed in a given time by a certain formation, and its capacity both of storing up as well as of releasing the once absorbed liquid, that is, the permeability of the beds. The existence of springs in these basins is thus the inseparable consequence of pan-formation by orogenic forces, though, of course, the possibility of their having been a cause may not perhaps be totally excluded.

As a last example, in the Ermelo and Carolina districts in the eastern Transvaal, several of these pans, far from being on the site of springs, have rivulets running into them.

The intimate relation of the origin of numbers of the pans to the action of mountain-folding forces, is again very markedly demonstrated by the direction of their longer axes, as also by the direction of the line or lines along which these pans are found, coinciding as they do with those of the axes of the folds in a given region.

The writer has already drawn attention to an exaggerated form of this same accident, the Rietkuil brachy-syncline in the Klerksdorp district.

The writer has shown that not only is the formation of pans one of the necessary results of the action of orogenic forces, but also that all the facts observed by different investigators in the study of this phenomenon are an equally necessary consequence of the origin contended for above.

IV.—Conclusions.

In conclusion, the writer's results may be summarized as follows:—

(1) The main directions of mountain-folding pressures have been north and south and east and west, the result of the former being predominantly evident in the central zone and that of the latter on the periphery of South Africa.

(2) These orogenic forces worked simultaneously and together built up the tectonic structure of South Africa, which may thus no longer be regarded and studied as the outcome of many different and local, that is, comparatively insignificant, causes, that have worked independently of one another.

(3) These systems of forces acted on all the strata of the geological systems, from the Primary upwards, either at different periods, or possibly during one long period, when there was active deposition of the younger sediments in one place, and denudation of the older in another.

(4) The origin of poorten, river-valleys and pans is traceable to the same causes which produced anticlines and synclines, brachy-synclines, basins or domes, that is, to fold-producing pressures, the former set of phenomena being, in fact, only modifications or diminutives of the latter.

Finally, the writer states that it is, of course, impossible, within the necessarily rather restricted limits of a paper, to discuss the many local problems which the tectonic structure of a region will often present. His intention, in placing these facts before the members, has been merely to direct their attention on very broad lines to the main laws which, it would seem, have governed the building of the South African continent, so that they may, perhaps, serve as a basis in the study of complicated local tectonic phenomena.

Mr. A. R. Sawyer (Johannesburg) said that Dr. Sandberg's paper was an important contribution to the study of the building

of the South African continent. He was in agreement, to some extent, with him as to the forces or tangential thrusts which tended to produce the tectonic phenomena found to-day. In his (Mr. Sawyer's) "Presidential Address" to the Geological Society of South Africa in 1905,* he touched on this subject, but whereas Dr. Sandberg was of opinion that the pressures came from the north, the south, the east and the west, his view was that these pressures came from the south and the east only, and that the pressures from the north and the west were more in the nature of resistances.

Dr. G. A. F. Molengraaff (The Hague) wrote that he agreed with Dr. Sandberg where he concluded that the main directions of mountain-folding pressures had been north and south, and east and west, in the Transvaal. He was of opinion that the value of Dr. Sandberg's paper would have been considerably enhanced, if he had described where pressure in one or the other of those two main directions prevailed during each of the subsequent geological periods.

He agreed at present with Dr. Sandberg's opinion that the Vredefort granite-mass was a denuded dome. He believed, however, that in the Vredefort area, as well as near Johannesburg, there was ample evidence of a powerful pressure from south to north in a period either entirely or at least partly subsequent to that of the deposition of the Pretoria (Gatsrand) beds. He was of opinion that the well known Jeppe's hill, north of Belgravia, where strata of the Vaal-river system (Elsburg beds and Klip-river amygdaloid) occurred in reversed stratigraphical order, must be regarded as an overthrust remnant (*lambeau de recouvrement*), pushed northwards by a powerful overthrust, and preserved from denudation by being jammed between two overthrust fault-planes.

The President (Mr. M. Deacon) moved a vote of thanks to Dr. Sandberg for his interesting notes on the structural geology of South Africa.

Mr. John Gerrard (H.M. Inspector of Mines) seconded the resolution, which was cordially approved.

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* "Anniversary Address," by the president, Mr. A. R. Sawyer, *Proceedings of the Geological Society of South Africa*, 1905, pages xvi and xvii.

A SINGLE-ROOM SYSTEM OF MINING: AN ADAPTATION OF THE LONGWALL METHOD TO WORK IN THICK SEAMS.

By H. S. GAY.*

By the term "single-room system" is meant a system by which the entire product from a series of entries is obtained from a single room; where each division of labour necessary to produce that product is regularly employed and at the same time. It is the outcome of an effort to work the longwall system. The mine where it is in operation is that of the Gay Coal and Coke Company, located in Logan county, West Virginia.

The seam of coal, 200 feet above the river-level, averages 5 feet 7 inches in thickness, dipping south and west about 1½ per cent. It is practically free of partings and of the nature of splint coal, the bottom bench rather strong and the top bench somewhat friable. The average thickness of cover does not exceed 500 feet, while the maximum is less than 1,000 feet.

The application of the longwall system of mining in moderately thick seams has been the dream of many mining engineers. It has been attempted several times in West Virginia, but, so far as the writer can learn, without success. The great difficulty has been to control the action of the roof.

The writer, not having the vision of a prophet, determined on the first suitable opportunity to give the system a trial, which opportunity in due time arrived. For the experiment, a section of the seam was selected where it could be most conveniently and quickly developed. A block of coal, ABCD, was cut by two longitudinal entries, Nos. 4 and 5, 600 feet long (fig. 1, plate xxii.), and one transverse entry, No. 2, 300 feet long, with the necessary air-courses separated from the entries by a pillar about 60 feet

* A paper read before the Coal Mining Institute of America, December 19th, 1906.

wide. It was proposed to mine the block by the retreating method, commencing at the eastern end, and working westward.

The character of the roof at that time was unknown, except that apparently it was good. From the nature of the work it was absolutely necessary that the roof be supported near the face of the workings at all times. To obviate the continual supply of timber which this provision would otherwise require, the writer designed a portable post.

These posts, 100 in number, are of beech or hickory, *a*, averaging 20 inches in diameter and 38 inches long. The top is covered with 1 inch poplar, *b*, and the bottom with $\frac{1}{16}$ inch sheet steel, *c*. Each post is mounted with a hydraulic head, which consists of a steel cylinder, *d*, 2 inches thick, one end closed and the other fitted with a cast-iron plunger, *e*, 12 inches in diameter, having a stroke of 4 inches (fig. 2, plate xxii.). The weight of each head is about 700 pounds. They were tested to a pressure of 3,000 pounds per square inch. The aggregate cost of the equipment was approximately £1,000. It was proposed to set these posts with 6 feet centres in two parallel rows, 3 feet apart (fig. 3, plate xxii.). The last row could always then be moved one at a time to an advanced position with safety.

Actual mining from the block was begun in January, 1905, the undercutting being done by a Morgan-Gardner electric longwall machine. The cars into which the coal was loaded entered No. 5 entry (fig. 1, plate xxii.), passed by the face, and after being loaded proceeded out by No. 4 entry to the tipple, as shown by the arrows.

As the work advanced, and the walls became over 30 feet apart, a row of props with 15 feet centres was set at intervals of 8 feet to 10 feet. After the distance between the walls had reached 60 feet, the portable posts were put into use. A row of 50 with 6 feet centres was set within 11 feet of, and parallel to, the working face (fig. 3, plate xxii.). The heads were covered with a wooden cap-piece and the plunger then raised by an initial water-pressure of 50 pounds per square inch, till the cap rested against the roof. The pressure was supplied by a pump at the power-house. A line of $1\frac{1}{4}$ inches pipe, *ab*, was laid from the pump to the workings, extending along the rib of No. 4 entry to the wall. This pipe was connected by a 50 feet length of indiarubber-hose, *bc*, to a line of $\frac{3}{4}$ inch pipe, *cd*, which was laid alongside of and fastened to the

track running parallel to the working-face, EF. Provisions were made so that the latter pipe could be connected to any one of the hydraulic heads by another 50 feet length of hose, *ef*. When the plunger had reached its limit, the pressure was retained by closing a valve, and the hose disconnected. In this manner each post was firmly set in place.

The next tier of posts, 50 in number, was set when the wall advanced 6 feet farther. As the work continued, the first tier was moved 3 feet beyond the second. Commencing at one end, each post was released and set in new positions successively by first opening the valve and releasing the plunger. The manner of moving them was by use of a jack, *g*, and chain, *j*, the posts being dragged along the bottom in an upright position (fig. 2, plate xxii.). This operation was performed by three men, followed by another who connected the hose to the hydraulic head and applied the pressure, which forced the plunger firmly against the roof. The time consumed was about 5 minutes for each post. An occasional row of props similar to the first was also set as a precautionary measure.

This work proceeded without difficulty until the walls, BC and EF, were 100 feet apart, and it was deemed advisable to bring down the roof and face the conditions that were to be confronted. The track was moved close to the face, and the portable posts set in a single row 6 feet from the face. Eighteen holes, 6 feet deep, were drilled in the roof in a line 10 feet from the posts. They were charged with dynamite. Holes were bored in twenty of the largest props, and also charged with dynamite. All were fired by hand in quick succession, and the result awaited with mingled curiosity and anxiety.

An examination in due time revealed the immediate roof to be a seam of strong sand-slate, at least 30 feet thick, without sign of a single parting. One block, 100 feet in length, had sheared close to the posts on the one side and to the opposite rib on the other. The sight of the space that it left directly above it, showing a vacancy equal in height to the one it had filled, foretold the difficulties to be encountered in prosecuting the longwall system.

At one point the slate had broken over the posts and covered the track for a distance of 50 feet. At least 150 feet of the roof remained undisturbed. Not one of the posts was broken, though

many of the plungers were forced to the bottom of the cylinders. For a period of 6 weeks the work was continued along this line. It was a constant and, at most times, a desperate struggle against the force of gravity; the output was reduced to less than one-half, though the cost of mining, while greatly increased, was less than by the room-and-pillar system. It was evident to those in charge that such a method could not be operated smoothly in a locality where labour was inexperienced and where the conditions of mining by other methods were the most simple. The chief difficulty was the possibility at any time of a mass of rock breaking directly over the posts and endangering the lives of the workmen.

While the writer was forced for a time to admit defeat, yet he has ever since thought that, had the roof been more to his liking, had it been stratified, or contained partings that would have allowed it to break behind the posts, he would have been successful. The enormous pressure—at times 300 tons or more on a post—was not due to the actual load, but to its leverage. Before it was safe to recover the posts, and in less than a fortnight, they were so completely covered by the débris that no two were visible at the same time.

The facility with which the coal could be moved, the concentration of labour, the need of so little skilled labour, the simplicity of the ventilation, and other features, revealed, in this brief experience, advantages which the writer was loth to lose.

In any method that he might adopt other than those in vogue in this locality, several conditions confronted him with which he had to comply: (1) The percentage of coal won must equal on an average that of the other mines in the same coal-field. (2) Since all the coal could not be removed by a single operation, pillars of some sort were a natural consequence. Therefore sufficient pillars must be left to sustain the roof for a length of time such as would allow each particular section to be mined in safety. (3) The proportion of narrow to wide work must be such that the additional cost of the former would be absorbed by the decreased cost of the latter.

Of the various schemes that suggested themselves, the following was adopted: It was proposed to work the remainder of the

block by a system of rooms each 80 feet in width, and one at a time, leaving a 30 feet pillar between (fig. 4, plate xxii.). Each room was opened by a sub-entry, and the manner of working thereafter was identical in every respect with the longwall system, the writer hoping thus to retain its advantages without being encumbered with its difficulties.

The dimensions adopted, which satisfied the three conditions, were based on the following assumptions: (1) Since it was already demonstrated that the roof was self-supporting at a span of 120 feet, it might with perfect safety be worked with a span of 80 feet. (2) If a vein of coal will support 5,000 feet or more of overlying strata, one-half the coal may therefore sustain 2,500 feet of strata, and likewise one-fourth of the coal may sustain 1,250 feet of strata. Thus 30 feet pillars, with regular intervening spaces of 80 feet to 90 feet between them, can for a time sustain the weight of 1,000 feet of strata. At least so it appeared to the writer.

In accordance with this hypothesis, a sub-entry, GH, 10 feet wide, was driven 30 feet from the abandoned wall and parallel to it. At a distance of 100 feet from the first sub-entry, a second one, IJ, was driven parallel to it as the coal from the first was being mined. This plan, it was considered, amply fulfilled the conditions to be met. It will be observed that the labour employed in mining is at all times working on the solid. Furthermore, in the event of a local or general squeeze, it is impossible for it to spread any further than the worked-out territory.

In the second room (fig. 5, plate xxii.), an attempt was made to mine without the use of portable posts, but they were again resorted to, as the roof gave evidence of having an initial strain, by the bursting-out of a triangular piece near the working-face. As the remaining rooms were enlarged, the roof continued to grow worse as it neared the outcrop, requiring at times auxiliary props close to the face to support the loose fragments of slate. Owing to the extremely poor roof, the rooms were gradually reduced in width, the last measuring but 60 feet.

From the knowledge gained by this experience, it was believed that with the roof in normal condition the rooms could be worked 90 feet wide, with 30 feet pillars between them, and therefore No. 4 and No. 5 entries were continued eastward to the line, and the sub-entries spaced accordingly for the rooms 6, 7, etc.

(fig. 5, plate xxii.). These sub-entries in this case were driven from both ends as the main entries proceeded.

Commencing with the last one driven, 12, it was widened to 40 feet, and a single row of ordinary timber-props, 8 inches to 10 inches in diameter with 15 feet centres, was set close to the face. At 50 feet, a second row was set; at 60 feet, a row of portable posts having 10 feet centres; and at 70 feet, a second row in the same manner. The ordinary props are used for the purpose of detecting the action of the roof. The remaining rooms in this tier were worked in the same manner. It may be remarked here, what is plainly evident, that as the room approaches its maximum width, the danger of a break in the roof also increases, and it is at this time that the greatest care should be exercised. Should there exist a fissure in the roof parallel to the working-face, without substantial supports its presence might prove very dangerous.

After a room has been finished, the track is removed. The work of removing the portable posts is begun in the middle, each half being hauled into the respective entries near the adjoining room.

Lately, the style of setting the posts on the heads has been adopted, supporting the latter on two pieces of wood, 2 inches by 6 inches and 2 feet long (fig. 6, plate xxii.). The work is thus simplified, to the extent that the labour is less to move and set the portable posts than it is to get and set the same number of ordinary props.

The first tier of rooms has now been exhausted, leaving but two fair-sized pillars between the first and last set to protect the haulage-ways. In the seven that have been driven under solid cover, there is as yet no sign of subsidence of the roof in any, except in the first worked, 12; and, strange to say, this subsidence is in the northern end, where it might least be expected, and was just as evident when the room was worked as it is now. At no point, however, are the overlying strata above 300 feet in height.

Fig. 5 (plate xxii.) shows the actual condition of the mine as it is to-day and the manner of keeping the work in advance. Mining has been started in the last room in the second tier. Since work began in room 12, a Sullivan electric chain-machine has been used, bought under a guarantee to cut the length of a room

in 10 hours. It has actually cut in 8½ hours 377 feet with an average depth of 6 feet 1 inch, thus preparing for the labour to follow over 500 tons of marketable coal.

An Agnew electric drill is used for drilling, by the use of which two men are enabled to drill and shoot the entire face inside of 10 hours. The holes are drilled 6 feet deep and about 10 feet apart. FFF powder is used, and in the rooms 180 tons are obtained per keg of 25 pounds.

Fig. 7 (plate xxii.) shows a truck for moving with a mule the hydraulic heads, which being circular can be easily rolled. The two side-pieces of this truck are made of 2 inches by 6 inches timber, and are held together by long bolts which can be loosened so as to spread apart the sides. In one side-piece there is a circular recess, in which is placed the projection in the bottom of the head (fig. 2, plate xxii.). The other side-piece has a projection, which enters a circular opening in the end of the plunger. The head may thus be hauled like a street-roller.

The cars pass continually in one direction, the loads at all times following the dip, and the empties immediately replacing the loads as they leave the room (the arrows in the entries show the direction taken by the cars). One mule can deliver regularly each day 100 tons to a distance of 1,000 feet from the working-face. As each cut is completed, the track is shortened in the entries, and the track in the room is swung the depth of a cut towards the face, and is always kept within convenient loading distance.

TABLE I.—HANDS EMPLOYED IN THE MINE.

Room: 300 Tons per Day.	No. of Men.	Entries: 60 Tons per Day.	No. of Men.
Cutting coal	2	Entry-men	6
Shooting coal	2	Machine-men	2
Scrapping bottom	4	Drivers	2
Loading coal	12	Trackman	2
Driving from room	3		—12
Extra driver	1	Foreman	1
Trackman	1		—
Posts and props	1	Total	39
	—26		

With the number of men that can be conveniently handled on a face of 300 feet, 300 tons is probably the maximum convenient tonnage per day from one room. Sixty tons per day from the entries will maintain sufficient development for this output. With a total output of 360 tons per day under the conditions described, Table I. shows the number of hands required inside

and the yield in tons per individual; being a yield of 9·2 tons per man inside. The number (39) is sometimes increased by the presence of a strong bottom clinging to the floor, requiring an increase in the number of scrappers, and by other minor causes.

The decrease in the yield following such additions is shown as follows: 39 men, 360 tons, 9·2 tons per day; 40 men, 360 tons, 9 tons per day; 42 men, 360 tons, 8·5 tons per day; and 44 men, 360 tons, 8·2 tons per day.

Between the various systems of mining under similar conditions, the basis of comparison is the yield per individual employed inside. In France this yield is less than 1 ton; and in Germany and Great Britain somewhat over a ton. In the bituminous coalfields of Pennsylvania, the yield is highest in the thick Pittsburg seam, varying from 4·5 tons to 5 tons per inside employé. In West Virginia, the most favoured places reach 5 tons, and sometimes exceed that quantity.

The yield is governed by conditions; probably the greatest skill in mining is shown in many cases where the yield is the least. The above figures would indicate, however, that in a vein 5 feet 6 inches to 5 feet 9 inches in thickness, under the most favourable conditions, 5 tons per employé is all that may be expected under the room-and-pillar system. In the system described, 60 per cent. more than this is readily obtained; 70 per cent. more without great difficulty; and 80 per cent. more is practicable.

In comparing the single-room with the longwall system, it is found that in the former, besides possessing greater safety, the yield per employé is not less than 20 per cent. more than the latter. Had the prosecution of the longwall system been sucessful, it would have required not less than 5 men under the most favourable conditions to protect those engaged in producing the coal. This labour is now sufficient to drive the sub-entries, thereby increasing the output to that extent. It requires much less skilled labour. Of the 26 men designated as being in the room, only one besides the foreman is a miner. The majority, as a rule, are inexperienced labourers. On the other hand, the longwall system yields nearly 20 per cent. more coal for the area mined. In the single room, as it was laid out, but 78 per cent. was recovered. Nevertheless, this equals the best results obtained

in West Virginia in veins of similar thickness and character of roof. The pillars left may not necessarily all be lost: possibly one-third of this coal could still be taken out; in fact, if the author were mining for a higher percentage in this direction, he would undoubtedly make an effort to recover some of it. But at this stage he prefers to let well enough alone. It must be remembered that this coal is mined in a region where but a short time ago land could be bought for £4 and less per acre. West Virginia has no home markets, and its coal is carried from 200 to 500 miles into the hearts of thriving coal-fields. Its commercial salvation lies in the quality of its coal and in cheaper mining than its competitors.

The writer has described the operation of a single unit of this system of mining. A similar set of entries in an opposite direction would double the capacity. Other modifications in their arrangement can be made to enlarge the output to any reasonable amount. Nor are the dimensions that he has adopted arbitrary. Under different conditions, it might be advisable to diminish the widths of the rooms and pillars. It is doubtful as to the system having much advantage over the room-and-pillar system with rooms less than 50 feet in width.

In conclusion, the writer would observe that a mechanical loader is not an impossibility, and the day may come, in some mines, when every division of the work will be performed or greatly assisted by mechanical means, and 10 tons per inside employé will be a regular and steady production.

Mr. H. W. G. HALBAUM'S paper on "Cast-iron Tubbing: What is its Rational Formula?" was read as follows:—

CAST-IRON TUBBING: WHAT IS ITS RATIONAL FORMULA?

By H. W. G. HALBAUM, Greenwell Medallist.

The Current Formulæ.—Attention has recently been directed by Mr. W. O. Wood,* by Mr. Isaac Hodges,† and others to failures of shaft-tubbing. Attention has also been called to the fact that, beyond the element of danger attaching to a fractured shaft, the cost, direct and indirect, of re-tubbing a shaft is out of all proportion to that which sufficiently substantial tubbing would have entailed in the first instance.‡ It has further been stated that there is some difficulty in fixing the proper dimensions of the tubbing required in any given case, owing to the mutual contradiction of current formulæ relating to the matter; and Mr. Hodges has given some very striking comparisons in a table.§ Mr. M. Deacon subsequently remarked that "He was glad to find that Mr. Hodges had departed from the old-fashioned rules regarding the strength of the tubbing. Everyone would agree that if he had taken one of the formulæ quoted in his paper, he would not have had to wait very long before the whole thing came in."‖ Again, in his "Presidential Address," Mr. Charles Pilkington stated that "although some formulæ are recorded in handbooks on mining, the information is untrustworthy, as little attention is paid to the depth and frequency of the flanges and ribs."¶ Still further, Prof. H. Louis raises another question, namely, whether the actual pressure is so arbitrary a

* "The Re-tubbing of the Middle Pit, Murton Colliery, 1903," by Mr. W. O. Wood, *Trans. Inst. M. E.*, 1904, vol. xxvii., page 197.

† "An Account of Sinking and Tubbing at Methley Junction Colliery, with a Description of a Cast-iron Dam to resist an Outburst of Water," by Mr. Isaac Hodges, *Trans. Inst. M. E.*, 1906, vol. xxxii., page 76.

‡ *Ibid.*, page 96. § *Ibid.*, page 96.

‖ *Trans. Inst. M. E.*, 1906, vol. xxxii., page 98.

¶ "Presidential Address" to the Manchester Geological and Mining Society, by Mr. Charles Pilkington, *Trans. Inst. M. E.*, 1906, vol. xxxii., page 360.

ratio of the head of water as all the formulæ assume:* he also notes the remarkably contradictory attitude of one rule to another; and he concludes by saying that no satisfactory tubbing rule has yet been framed. All the critics, above quoted, are men whose views are entitled to substantial respect.

The Necessity of Examining the Formulæ.—In order to ascertain, if possible, what ground exists for this general distrust of current formulæ, the writer has collected together all the tubbing rules he can find, namely, those associated with the names of Messrs. J. J. Atkinson, G. C. Greenwell, G. G. André, W. Galloway, G. H. Hollingworth, W. Tate, and W. S. Aldis, the last named being No. 42 formula in Mr. J. H. Merivale's *Notes and Formulæ for Mining Students.*† There may be other rules (the writer possesses few strictly mining books), but the seven referred to should be sufficient for the present purpose. It will be observed that at least two of this number are modern (since their authors remain with us), and not to be included in the category of "old-fashioned rules" so whole-heartedly condemned by one of the speakers above quoted. It may be remarked that one does not condemn a rule simply because it is old-fashioned. It may be that, but it is not necessarily out-of-date on that account. Still, it is necessary to have authoritative teaching as to the means by which the permanent security of costly shafts may be achieved. The supreme importance of the matter demands the immediate attention of those men who aspire in any measure to be constructive teachers of mining technique. It is important to criticize unsound formulæ, but it is of greater importance to construct something better to put in their place.

A fairly adequate examination of current formulæ has convinced the writer that, from the practical standpoint, engineers are left in chaotic confusion, owing to the mutual contradiction of the several rules. The rules differ widely with respect to the numerical values employed to represent a given factor; and, what is worse, they differ with regard to the fundamental principles which they take into account. Again, as will

* *Practical Coal-mining*, by Leading Experts in Mining and Engineering, under the Editorship of Prof. W. S. Boulton, 1907, divisional volume i., page 137.

† First edition, 1887, page 24.

be presently proved, not a single rule of the seven mentioned is a "rational tubbing rule." The term "rational" is used in its ordinary scientific sense, as opposed to the quality of empiricism: this last word being construed in its best sense. A rational rule proceeds on established principles; an empirical rule rests on more or less practical data the underlying principles of which are not understood. None of the current tubbing formulæ are rational. Some of them again are neither rational nor empirical; they are simply sciolistic. That is to say, they are standard rational formulæ wrested from their original and legitimate connections, and made to do duty under circumstances which they were never designed to embrace. The writer is, therefore, obliged to conclude that the general distrust of the current tubbing formulæ is amply justified; and he believes that the whole of these rules, including the modern as well as the older examples, are irrational in theory and misleading in practice.

In common fairplay, however, a word should be said in extenuation of the framers of these formulæ, and it is this: sound scientific formulæ can be evolved only from sound experimental data. But these practical data can be supplied only by practical men, from the stores of their united practical experience. And practical men may be asked if, in the past, they have always given of their practical data as generously as they might have done. If they have not, they can scarcely now, with any pretence of justice, tilt at the "theorists" for failing to make perfect bricks (in the shape of rational formulæ) without straw (in the shape of experimental data). The present scantiness of knowledge in this and many other directions must not be attributed to the theorists alone—it is far more to the point to say that, in spite of all the work of our institutes, technical poverty is part of the price now being paid for the repugnance of the individual practical man to divulge the nature of his collected experimental data, lest, haply, the knowledge should prove of value to others.

Neither can one even appear to depreciate any work of such men as Messrs. J. J. Atkinson and G. C. Greenwell without a word of explanation, nor yet without a tribute of admiration to the great qualities of these grand old engineers of British mining. Mr. Atkinson's formula is a perfectly rational formula for thin cylinders subjected to hydraulic pressure only. Its great defect as

a tubbing rule is, that it fails to take into account the possibility of chemical action on the metal. It is a pressure-formula only, and may safely be employed in cases where the tubbing is subjected to pressure only, provided that pressure is not excessive. Mr. Greenwell's wellknown rule allows something for chemical action on the metal, as well as for the hydraulic pressure thereon. It was probably put forward as an empirical rule closely corresponding with the mining practice and technical standards of Mr. Greenwell's time. Tubbing put in according to this rule, in shafts piercing moderately firm strata containing feeders of water distinctly corrosive, without being excessively so, may, in the writer's opinion, be relied on for something like half-a-century's service. And, when Mr. Greenwell wrote, it is probable that few shafts were expected to have a longer working life than the period named. There are, therefore, individual cases even now where one or other of these two formulæ might be safely employed to fix the strength of the tubbing. The principal danger lies in the fact that many practical men are unable to analyse the precise conditions and the exact requirements of each individual case. Indeed, all formula-makers, past and present, appear to have been alive to this danger. So far as the older writers are concerned, it may have been a necessity of the times in which they lived; but however that may be, they all endeavour to take the responsibility from the practical man. And, to this end, their formulæ take no account of local circumstances, except the diameter of the shaft and the head of water. These two being given, the required thickness of the tubbing, by any given formula, is irrevocably fixed, irrespective of time, place, and general environment. A speaker commenting on Mr. Hodges' paper said that " the question of the strength of the tubbing required unfettered consideration, from the point of view of the greater diameter of the shafts now than in the past."* If this means that the current formulæ ignore the diameter, the present writer has been unable to find an instance of it, and certainly none of the formulæ quoted by Mr. Hodges furnishes such an instance.

The Current Formulæ are not General Formulæ.—Now that the writer's attitude is made plain, it may be well to illustrate, by a single example, the contradictory teaching of the current

* *Trans. Inst. M. E.*, 1906, vol. xxxii., page 98.

formulæ. Example: 450 feet of open-topped tubbing in a shaft of 20 feet diameter. What should be the thickness of the bottom ring? Messrs. Greenwell and André (by their formulæ) make it 2½ inches; Mr. G. H. Hollingworth's formula* makes it 3 inches; Mr. W. Tate's rule, quoted by Mr. Hodges,† makes it 3½ inches; whilst Mr. Galloway's rule, quoted by Prof. Louis,‡ puts the safe thickness at something less than 0·90 inch. This mutual divergence does not actually prove that no one of the rules is a general one, but it furnishes a presumption to that effect.

No Current Formula is a Rational Formula.—That none of these rules is, in the scientific sense, rational, is proved by the fact that each of them employs constant numerical values to represent factors which are by no means constant between one case of practice and another. What, for instance, is the use of employing figures implying that the ultimate crushing strength of cast-iron in pounds, or in tons, or even in tens of tons per square inch, can be expressed as a numerical constant correct to five significant figures, when no dependence can even be placed on the first figure? If it be said that the numerical values of a formula represent average values, what about the safety of the tubbing when the metal is below the average? If, on the other hand, it be said that the numerical values of the formula represent minimum values, what about the economy of tubbing made of good material? It is obvious that if an engineer orders metal of a higher quality, and exacts certain guarantees, such as proof tests or tests to destruction, from the founders, he may legitimately count on a higher value of the safe stress than if he had ordered his metal anyhow. But so soon as he acts on scientific principles, that is to say, so soon as he acts rationally, he departs from the formula. Hence the formula cannot be a rational formula.

In the better examples of current formulæ, the thickness of metal required by the pressure forms only a portion of the total thickness, the remainder being designed to cover waste due to corrosion and wear-and-tear. This allowance, by Mr. Greenwell's

* *Practical Engineer Pocket-book*, 1903, page 530.

† "An Account of Sinking and Tubbing at Methley Junction Colliery, with a Description of a Cast-iron Dam to resist an Outburst of Water," by Mr. Isaac Hodges, *Trans. Inst. M. E.*, 1906, vol. xxxii., page 96.

‡ *Practical Coal-mining*, by Leading Experts in Mining and Engineering, under the Editorship of Prof. W. S. Boulton, 1907, divisional volume i., page 138.

formula, is 0·03 feet or 0·36 inch, while Mr. André puts it at 0·35 inch; and, right or wrong, therefore, these older authorities are in practical agreement. Of the two more modern authorities, one, Mr. G. H. Hollingworth, increases Mr. Greenwell's 0·36 inch to 0·50 inch; and the other, Mr. W. Galloway, reduces it to zero, and allows nothing at all. Whether the member of waste be taken at nothing, or at 0·50 inch, or at any other constant figure, its inclusion in the formula as an arbitrary numerical value applying to all cases alike at once renders that formula illogical and misleading from the practical standpoint, and irrational in the scientific sense of the term.

Corrosion, wear-and-tear, and waste show (1) the work performed by certain agents; (2) a work the ultimate quantity of which depends on (*a*) the strength of the agents of waste, and (*b*) the duration of the time that they are allowed to work. The wear-and-tear of an engine will be greater at the end of 10 than at the end of 5 years. The corrosion of metal under water continuously will be more pronounced after 100 than after only 20 years. And, again, the corrosion of one kind of metal by one quality of water during 20 years may be greater than the corrosion of another kind of metal by a better kind of water during a century. Now, since mine-waters vary with regard to their contained impurities, the force of the corroding agents at work on tubbing varies between colliery and colliery. The duration of the corrosive action (so far as it is necessarily taken into account) is measured by the working life of the tubbed shaft; and this working life may be very much greater in the case of one than in the case of another shaft. Hence the allowance for waste of metal should vary as the power of the corrosive agents multiplied by the estimated working life of the tubbed shaft; and the rational allowance for waste cannot be represented for all cases alike by 0·36 inch, or by 0.50 inch, or by any other numerical constant. To say that it can is equivalent to saying that the working life of any given colliery, multiplied by the corrosive properties of the local water, is equal to the working life of any other colliery, multiplied by the corrosive properties of the local water. In other words, it is equivalent to asserting that the corrosive properties of local water vary inversely as the working life of the colliery. Therefore it is equivalent to saying that the corrosive properties of local water can be reduced to the smallest possible value by simply deciding to ex-

tend the life of the colliery to a sufficiently distant period. Hence, in any rational formula applicable to the general case, the allowance for waste cannot be stated as an arbitrary and eternally constant numerical value; and it would be just as rational to suppose that the diameter of the shaft, or the head of water, can be expressed in the general formula as a numerical constant.

The Properties of a Rational Formula.—The ideal rational formula correlates the various principles affecting the general case. The numerical values of the algebraic factors must be substituted by the engineer-in-charge of the particular shaft. The actual rational formula correlates the general principles as efficiently as the present state of knowledge permits. The actual rational formula, therefore, is not necessarily a perfect formula; and that is so because the present state of knowledge, upon which the formula is based, is not perfect. A rational formula, therefore, embraces the principles that are known, and it ceases to be a rational formula so soon as newer principles bearing on the case are discovered. But, in all cases, the rational formula indicates general and known principles; and in all cases of individual practice, the engineer-in-charge must make the local application of those principles on his own responsibility. All that the rational formula professes to do is to indicate the principles affecting the case and the nature of their interrelation, and it affords a safeguard against oversight and inadvertence.

The Rational Tubbing Formula.—The rational tubbing formula must determine the thickness of tubbing required for any particular case. Let the total thickness be T inches: then the present state of knowledge teaches that T, reduced to its simplest and most comprehensive terms, is the equivalent of a binomial, namely:—

$$T = t_1 + t_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where t_1 is the thickness in inches necessary to cover the waste of metal; and t_2, the thickness necessary to be maintained against the pressure proper throughout the entire life of the mine. But just as T is the sum of t_1 and t_2, so also are t_1 and t_2 the quotients of various factors divided by others. These factors must be found, if possible, and placed in their proper relations one to another in a rational formula. As set forth in the formula (1), T is the

sum of two terms, or members: t_1 being the corrosion-member, and t_2 the pressure-member of the rational tubbing formula.

The Known Factors of the Corrosion-member.—It is usual to speak of the corrosion and wear-and-tear of the tubbing. The wear-and-tear is a very vague and uncertain quantity; and there is some difficulty in conceiving what wear-and-tear can occur with shaft-tubbing, if the term be used as in any sense similar to the way in which it is applied to the wear-and-tear of an engine, a wheel, a rail, a rope, or any other structure dealing with a live load. There must be some little wear-and-tear with a dead load also: hence there must be some on the tubbing supporting the dead load of water behind it. But such mechanical wear-and-tear must be so infinitesimal, compared with the chemical action of corrosion, that the two may be considered together as simple corrosion. In any case, both alike are the work of time; and equally in any case, the two would be impossible of separate measurement in practice. Hence, in the present state of knowledge, it is convenient to assume that the "factors of corrosion" include all factors of waste that require time to develop certain given results. In these are included (1) the factors of corrosion by water, (2) the factors of corrosion or oxidation in the shaft-atmosphere, and (3) the factors of mechanical wear-and-tear.

The rational factors of t_1 are easily stated in algebraic form. Let the estimated working life of the newly tubbed shaft be l years, and let it be estimated that the factors of corrosion are capable of eating into the metal at the rate of $\frac{1}{n}$ inch per annum; then the corrosion-member of a rational formula must be t_1, and

$$t_1 = l \times \frac{1}{n} = \frac{l}{n} \text{ inches} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

It is obvious that $\frac{l}{n}$ is the only rational value of t_1 and it is the place of the practical man to substitute, in each particular case of practice, the proper numerical values of l and n. And since the practical man has been so severe on Mr. Greenwell and others who have given empirical values of $\frac{l}{n}$, he will doubtless have little difficulty in fixing the rational numerical value himself. Seriously, however, in any particular case the estimation

of the numerical value of l should be a comparatively easy matter, but that of n will be more difficult to get at. Analyses of shaft-waters and the probable shaft-atmosphere (if it be an upcast) will be required. The probable nature of the shaft-atmosphere will be the same as that of the nearest pit already in full work. But, these analyses having been obtained, the corrosive power of the ingredients requires to be accurately known. There might have been much knowledge of this kind available, had the opportunities of the past been utilized. As it is, the desired knowledge of the corrosive properties of various mine-waters is not to hand, and it can only result after extended experiments.

The Class of Data Required.—Prof. J. Clerk Maxwell states that "the most important step in the progress of every science is the measurement of quantities. Those whose curiosity is satisfied with observing what happens have occasionally done service by directing the attention of others to the phenomena they have seen; but it is to those who endeavour to find out how much there is of anything that we owe all the great advances in our knowledge."* Some remarkable instances of the corrosion of cast-iron exposed to the action of water for many years have recently been recorded in mining literature. These records, however, are deprived of commercial value by the regrettable fact that the work of the corrosive forces was not measured, nor was any attempt made to measure it. One can only suspect, without being (from these records) able to prove, that the corrosion-member in the rational tubbing formula may, in many cases, represent a numerical value far greater than many people imagine to be possible. The required data are those of measured quantities, and these must be supplied by practical men.

Mr. Isaac Hodges' Experiments.—Mr. Hodges has made a series of experiments on tubbing which had stood in a downcast shaft for about 50 years.† Selecting six consecutive rings of tubbing, test-holes were drilled in every segment thereof to determine the thicknesses. The various segments showed great

* *Theory of Heat*, by Prof. J. Clerk Maxwell, tenth edition, 1891, page 74.

† "An Account of Sinking and Tubbing at Methley Junction Colliery, with a Description of a Cast-iron Dam to resist an Outburst of Water," by Mr. Isaac Hodges, *Trans. Inst. M. E.*, 1906, vol. xxxii., page 78, table ii.

differences in strength. In one particular ring, the maximum thickness was 1 inch; the minimum $\frac{7}{16}$ inch. Mr. Hodges does not appear to state what was the original thickness, but it is fair to assume that segments of the same ring would be originally put in of equal thickness; and the natural inference is that the difference between the maximum and minimum thickness found after 50 years was eaten away in the interval by the corrosive agents contained in the mine-waters, on the one hand, and in the shaft-atmosphere on the other. The difference was $\frac{9}{16}$ inch.

It is practically certain that the actual maximum corrosion was greater than $\frac{9}{16}$ inch, for this figure represented merely the difference of corrosion as between the best and the worst segments of the ring; and it is very certain that the least corroded segment was not actually a non-corroded plate. The actual maximum, therefore, would be equal to $\frac{9}{16}$ inch *plus* the corrosion of the best-preserved plate in the ring. Mr. Hodges appears to have fully appreciated this side of the problem, for on each segment of his new tubbing he "had the thickness cast on the inside face in relief figures, for future reference and testing in coming years."* It is very certain, therefore, that the maximum corrosion was more than $\frac{9}{16}$ inch. If it be assumed that the corrosion of the worst-preserved segment was four times as great as that of the best-preserved segment, the maximum value will be $\frac{3}{4}$ inch and the minimum value $\frac{3}{16}$ inch: for the difference of 4 to 1 is 3, but the actual difference was $\frac{9}{16}$, hence, as $3:4, \frac{9}{16}:\frac{3}{4}$. Consequently, the maximum corrosion effected during 50 years was equal to $\frac{3}{4}$ inch of solid plate, representing a rate of, say, $\frac{1}{67}$ inch per annum, that is, the corrosive agents at Methley Junction colliery are capable of eating away one inch of metal in a period of 67 years.

Available Data respecting Corrosion.—Whether the rate obtaining at Methley Junction colliery represents an altogether extreme case or not is very difficult to say, as the available data are not sufficient to entitle one to express an opinion. The literature of iron-shipbuilding may furnish some data, but the literature of mining appears to be altogether deficient in this

* "An Account of Sinking and Tubbing at Methley Junction Colliery, with a Description of a Cast-iron Dam to resist an Outburst of Water," by Mr. Isaac Hodges, *Trans. Inst. M. E.*, 1906, vol. xxxii., page 80.

respect. Corrosion in steam-boilers is not analogous: for, in the tubbing question, the temperature-factor is absent. Tables given by Sir Guilford Molesworth* suggest that the corrosive agents are much less energetic, but the waters there taken into account are not mine-waters. On the other hand, the phenomena observed on the re-opening of Hartley colliery,† after the colliery had been drowned for 40 years, suggest that the rate of corrosion at Methley Junction colliery may not be so great as one would fain hope. On re-entering this historical mine at Hartley, Mr. R. E. Ornsby found that "cast-iron pipes were covered by a thick incrustation of iron oxide, in which shale and coal were embedded, and cast-iron tub-wheels were similarly incrusted. Wrought-iron rails and picks and all parts of tubs made of wrought-iron were also incrusted, but, unlike cast-iron, the wrought-iron had been diminished in size, being partially eaten away, while the cast-iron was altered in its nature, and looked like indurated clay."‡ In the discussion of this paper, Prof. R. A. S. Redmayne (the then manager of the colliery) said that "the iron itself was completely changed: it was as light as brown paper, and looked like graphite."§ And he subsequently added this very material bit of information: "The water . . . . was as nearly as possible a saturated solution of salt, and it was probably derived from the sea."‖ Mr. T. E. Forster stated that "the experience with regard to cast-iron was exactly the same as they met with at Wallsend colliery, a pit which had been under water for about 40 years."¶ Now, in comparing notes, it must be remembered that 40 years was also the measure of the time during which Hartley colliery was drowned, and also that the Wallsend water cannot be derived from the sea. Hence, it appears that similarly energetic corrosive action occurs at Hartley, on the sea-coast, and at Wallsend, which, though not far distant from the coast, is yet sufficiently distant to warrant the assertion that its waters are land-waters.

* *Pocket-book of Engineering Formulae*, twenty-third edition, 1896, page 42.

† "The Re-opening of Hartley Colliery," by Mr. R. E. Ornsby, *Trans. Inst. M. E.*, 1905, vol. xxix., page 657.

‡ *Ibid.*, page 660. § *Ibid.*, page 663.

‖ "An Account of Sinking and Tubbing at Methley Junction Colliery, with a Description of a Cast-iron Dam to resist an Outburst of Water," by Mr. Isaac Hodges, *Trans. Inst. M. E.*, 1906, vol. xxxii., page 95.

¶ *Trans. Inst. M. E.*, 1905, vol. xxix., page 663.

Mr. Sydney F. Walker's corrosion theory is so very suggestive, that one cannot refrain from quoting it in this important connection of preservation of tubbing. In the discussion on Mr. Ornsby's paper above referred to, Mr. Sydney F. Walker gave his opinion, as an electrical engineer, "that the action of the salt-water on the iron was an electrical one. Wrought-iron was almost pure, and if oxygen were present in any form for which the metal had an affinity it simply ate away the iron. In the case of cast-iron, they had practically an alloy of iron and carbon, the carbon being in very much greater quantity than in wrought-iron. It must be borne in mind that time was a factor of great importance. In this case, the lapse of time was considerable, and he thought that in the cast-iron they would have iron and carbon in a more or less mechanical mixture with other things. This dirt was partly dissolved out, and they had the salt-water getting in between the carbon and the iron, forming at once a galvanic battery. The iron became oxidized, and other actions following between the new substance and the carbon produced gradually another substance which had been described as indurated clay."* This theory may or may not be absolutely sound, but it is at least extraordinarily suggestive; and it certainly shows that in estimating the probable corrosion of one substance in presence of another, the "electrical attitudes" (so to speak) of the substances must be taken into account.

It will be admitted that the estimation of the numerical value of n which is to be substituted in the rational formula in any given case of practice is at present a problem of great difficulty and great complexity; but it is certainly the only rational solution of the tubbing difficulty, so far as the allowance for waste is concerned. What then can be done? The immediate duty is certainly plain: it is to set about and find the practical data relating to the case; and if they cannot be found ready-made, they must be made. For example, it would add to the value of Mr. Hodges' already valuable work, if he now furnished a more detailed description of the exact nature of the 113 grains of solid matter per gallon and other insidious impurities contained in the water of the Methley Junction shafts.† And, if Mr. Ornsby, and other

* *Trans. Inst. M. E.*, 1905, vol. xxix., page 664.

† "An Account of Sinking and Tubbing at Methley Junction Colliery, with a Description of a Cast-iron Dam to resist an Outburst of Water," by Mr. Isaac Hodges, *Trans. Inst. M. E.*, 1906, vol. xxxii., page 95.

engineers with similar opportunities, would institute at other collieries experiments similar to those undertaken by Mr. Hodges, very soon a mass of data might be tabulated for general reference. Such tabulated results might include: (1) the name of the colliery, (2) the name of the experimenter, (3) an analysis of the shaft-water, (4) an analysis of the return-air, (5) the quality of iron composing the tubbing, (6) the nature of the strata in the shaft, and (7) the amount of corrosion proved to have taken place during x years. The value of this tabulation for general reference is too obvious to need any illustration.

The Effect of a Back Lining.—Where the corrosive agents are as active as those at Methley Junction colliery, the allowance for waste alone would require to be 1½ inches, if the tubbed shaft were required to stand 100 years. In such a case, the engineer might decide to use a lesser thickness of metal, and back it with a lining of some material that was supposed to be able effectually to prevent the water from making actual contact with the metal, although the tubbing, of course, would ultimately take the whole pressure. In that case, the value of $\frac{l}{n}$ would, numerically, be zero, or nearly so, since the waste would now be limited to the weathering of the concave surface in the shaft-atmosphere and the mechanical wear-and-tear, whatever that shadowy entity may be. Nevertheless, it is questionable whether so perfectly efficient a backing material really exists. Such a material, it is plain, must not itself be corrosive; it must not be porous under pressure, neither must it be liable to crack by reason of slight earth-tremors due to the radiative draw of the strata towards the more or less distant goaves of the mine, or towards the depressions left by running sands contained, maybe, in the circumjacent strata. Such a perfect material may possibly exist; it may even be available: so much the better if it is, but opinions seem to differ on the point. As an illustration of apparently divergent views, two recent practical examples may be cited.

(1) When Mr. W. O. Wood re-tubbed the middle pit at Murton colliery, he backed the new tubbing with a lining of carefully prepared cement-concrete. He lays emphasis on the fact that the materials were carefully prepared; and he thinks, that with this

lining to resist it, the water can have no effect on the new tubbing.*

(2) On the other hand, when Mr. Hodges re-tubbed the Methley Junction shaft, he coated each separate piece of metal with Dr. Angus Smith's composition, and afterwards backed the joined-up tubbing with concrete (whether or not that was prepared with extra care he does not say); but, after doing all this, he placed so little confidence in the efficiency of the arrangement to prevent corrosion that he allowed, over and above the thickness due to the pressure, an additional thickness of metal amounting to $\frac{9}{16}$ inch, all the way down, to cover the risk of corrosion. Mr. Hodges does not state the fact in so many words, but an examination of Table VI.† shows that the various thicknesses of tubbing at various depths of his 10 to 11 feet shaft agree absolutely with the following formula:—

$$T = \frac{9}{16} + \frac{H}{320},$$

where T is the thickness of the tubbing in inches; and H, the height of the tubbing in feet.

Possibly Mr. Wood's cement was the more elaborately prepared of the two, and whether it will have a correspondingly greater efficiency remains to be seen. The two cases show a wide difference of views, as to whether a concrete-lining can really be depended upon to prevent the water from ultimately finding its way to the metal beyond. And if there be any doubt on the matter, then, until further data are forthcoming, the only course which is obviously safe in any particular application of the formula is to disregard the lining in its supposed office as an impenetrable barrier, and to give $\frac{l}{n}$ the same numerical value as it would naturally receive if the lining were known to be porous, cracked, or otherwise inefficient.

Synopsis.—The first member of the rational tubbing rule, the extra thickness of the tubbing required to allow for waste, is:—

* "The Re-tubbing of the Middle Pit, Murton Colliery, 1903," by Mr. W. O. Wood, *Trans. Inst. M. E.*, 1904, vol. xxvii., page 204.

† "An Account of Sinking and Tubbing at Methley Junction Colliery, with a Description of a Cast-iron Dam to resist an Outburst of Water," by Mr. Isaac Hodges, *Trans. Inst. M. E.*, 1906, vol. xxxii., page 96.

$$t_1 = \frac{l}{n} \text{ inches,}$$

where $t_1 = T - t_2$; where t_2 again is the normal thickness required by the proper pressure.

Whatever difficulty may occur in any given case of practice, with regard to substituting in the formulæ the locally correct numerical value of n, clearly arises from the lack of practical data such as practical engineers alone can supply, but such, however, as practical engineers are also well able to furnish if they care to put themselves to trouble for the general good. Before passing to the consideration of the rational value of t_2, the writer will briefly recapitulate the argument relating to the case of t_1. It is perfectly clear, therefore, that:—(1) The rational value of t_1 is not a numerical constant applying to all cases alike. (2) In the present state of knowledge the only possible rational value of t_1 is $\frac{l}{n}$. (3) The only difficulty in applying this value in practice arises from a lack of the necessary data. (4) The necessary data can be supplied only by practical engineers from their united experiences. (5) Practical engineers are well able to furnish the required data. And (6) if (1), (2), (3), (4), and (5) are true, it must also be true that $\frac{l}{n}$ is an accessible and get-at-able value of t_1, susceptible of employment in practice, as well as the only rational value consistent with known facts.

The Pressure-member of the Rational Formula.—The next step is to substitute in equation (1) the value of t_1 given by the equation (2), and obtain:—

$$T = \frac{l}{n} + t_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

and t_2 is the pressure-member of the rational formula. The succeeding step is to seek the rational factors of t_2.

The completed tubbing in a mine shaft may be practically defined as a vertical cylinder, subjected to external pressure exerted horizontally. Each separate ring of tubbing may be legitimately conceived to form a complete cylinder in itself, sustaining a pressure greater than that on the ring above and less than that on the ring below. The connections of the ring with the rings immediately above and below it serve the purpose of more

certainly assuring the rigidity of its two ends—an important consideration in any problem dealing with the strength of such cylinders as those under investigation. The cylinder, then, is a cylinder with rigid ends. The writer will use the following definitions:—The "cylinder" is any given ring of tubbing; the "column of tubbing" is the whole height of the completed tubbing; and a "given perimeter" is the perimeter of the tubbing in any given horizontal plane.

Since any structure is no stronger than its weakest part, it is evident that t_2 is the least thickness required in the cylinder, in view of the pressure which it is called upon to resist. It is the effective thickness; indeed, all the three members of equation (1) must be understood as representing in each case the effective minimum: of the total thickness T, of the corrosion member t_1 and of the pressure-member t_2. No rational formula will contain a *plus* numerical constant to provide against imperfect castings; for that provision must be made by the practical engineer on the spot, and the quantity of allowance must depend on the local circumstances of the case, and on the nature of the iron-founders' guarantees. When the theorist states that $\frac{1}{4}$ inch or thereabouts must be allowed for imperfections in the castings, he is exceeding his duty as a theorist, and usurping the office of the practical engineer, who is placed in charge of the local case in order to determine, for that particular case, the proper numerical value of this "thereabouts" and other varying quantities. Therefore, in this section of the investigation, t_2 is the effective thickness, and it is the concern of the practical engineer to see that the difference between the effective thickness and the apparent thickness is as precise as safety and economy will permit.

Whatever rational tubbing formula may be held to apply, it must proceed on the assumption that the perimeter is originally a circle, whatever shape it may ultimately possess. No one formula can rationally apply to a thousand-and-one ill-defined shapes, which, in the first instance itself, can only be described as approximately circular. Here, again, the theorist must not exceed his limits; he may build up his rational formula on the assumption that the tubbing is circular, but it is the concern of the practical engineer to see that it is actually circular, just as much as it is his place to see that the whole column is set plumb.

The rational formula for t_2 can apply only to normal cases:

a shaft passing through water-bearing strata is a normal case, even though the water-bearing strata contain beds of quicksand at great depths from the surface: for the statical pressure of the sand and water can be calculated beforehand, and their wearing effect on the metal can be provided against beforehand. But, if the quicksand afterwards flows away from the shaft, leaving a large cavity of wide area behind the tubbing (and such cases are not unknown), the case then ceases to be normal. For the liability of the roof of the cavity to fall and (by means of the remaining sand and water) transmit its kinetic energy in force against the tubbing, opens up abnormal possibilities the full measure of which cannot be calculated beforehand. And, therefore, the strength of the tubbing required to withstand successfully the abnormal onslaught cannot be calculated beforehand. Neither can any rational formula be framed such as would define the dimensions of efficient tubbing to be placed in a shaft, which is thereafter straightway undermined and shattered by the removing of coal that ought properly to form part of the necessary shaft-pillar.

So far as the factors of t_2 are concerned, all the current formulæ known to the writer are crushing formulæ. And so far, probably, as most engineers who have examined these rules are concerned, the present question (apart from that of t_1) is whether any one of these rules is a crushing formula rationally applicable to the normal tubbing case. But in the opening paragraph of this paper, Mr. Charles Pilkington is quoted to the effect that current formulæ are untrustworthy, by reason of the fact that they pay little attention to the depth and pitch of the flanges and ribs. This criticism evidently raises the previous question as to whether any simple crushing formula whatever is capable of supplying a rule rationally applicable to the tubbing case. It is herein implied that a really rational formula must take account of the ribs and flanges: that it must deal with the stiffness of the tubbing, and, therefore, with the resistance of the cylinder to collapse. Hence, it seems to be implied that, with regard to t_2, the rational formula is not one of simple crushing, but of combined crushing and bending: in short, that it is a collapse formula after the model, presumably, of Sir William Fairbairn's well-known rule relating to furnace-tubes in boilers—modifications of which rule have been from time to time proposed by

various authorities; amongst whom may be mentioned Messrs. W. C. Unwin, A. F. Seaton, M. Longridge, and even the Board of Trade. This, then, is the previous question demanding to be considered: Is the rational formula for t_2 a simple crushing formula? Or, is it a collapse formula which determines the stiffness of the tubbing as set forth in the depth and pitch of the various ribs and flanges?

Collapse versus *Crushing*.—The question, just raised, naturally resolves itself into three distinct queries, namely:—(1) Whether, in the normal tubbing case, the factors of collapse are present; (2) if present at all, to what extent they are effective; and (3) to what extent it is necessary in a rational tubbing formula to take those factors of collapse into account.

It is necessary to ascertain what external factors of collapse are present. It is known that all arches are liable to collapse, if the various thrusts at various points of the curve are not opposed by their various proportional resistances. And, looking at the case in this very general way, it might at first sight be supposed that the tubbing is safe against collapse. For, at all points in a given perimeter, the thrusts, in the ordinary tubbing case, are equal to the degree of ideality. Generally, the pressure is almost entirely a fluid pressure, and fluids exert equal pressure in all directions at any given horizontal plane in the fluid. And if, in addition to the fluid pressure, there are other pressures on the tubbing, these also are calculated from a common horizontal datum plane directly above the horizontal plane in which the given perimeter is contained. Then, since all the pressures on the given perimeter are equal, and since t_2 is of the same value all round the perimeter, it is not easy to see how collapse can occur so long as t_2 is large enough to provide against the simple crushing stress. For collapse is the result of bending, and there appears to be little liability of bending where the whole system of pressures is so excellently adjusted.

There is another standpoint, however, from which the question may be argued: instead of a masonry arch, consider a furnace-tube within a steam-boiler of the Cornish or of the Lancashire type. Here the liability to collapse arises from the unequal expansion of the tube induced by unequal temperatures over various portions of it. Unless sufficiently stiffened by flanges,

hoops, or corrugations, the tube will collapse; for the effect of the unequal expansion is to transform the originally cylindrical tube into a sub-cylinder. This departure from circularity invites collapse, and is, indeed, the invariable antecedent of collapse. But in the normal (and modern) tubbing case, the temperatures obtaining around the whole length of any given perimeter are equal temperatures (since the antiquated custom of bratticing a single shaft into intake and return air-compartments no longer obtains). Hence, the pressures being equal, and the temperatures being uniform at all points of the perimeter, the circular tubbing has no cause to depart from its originally circular form, and, therefore, there is little occasion to fear that it may perish by collapse.

It will be advisable to analyse this position a little more minutely, since the object now is to fix and define the precise significance of the ribs and flanges of the tubbing; and the argument of the two preceding paragraphs may be considered from yet another standpoint. Take the case of what the engineer calls "long columns." These are liable, as is well known, to perish by collapse long before simple crushing-stress limits are reached. At first sight it seems a far cry from rings of tubbing and furnace-tubes to long columns; but there is an intimate analogy between the two problems, as Prof. Unwin has pointed out.* In fact, the following argument on the tubbing case presented itself to the writer after he had studied Prof. Unwin's position on the problem of furnace-tubes and provision against their collapse. The argument, therefore, is hardly to be described as original to any notable degree; but it has at least the merit of being absolutely simple to understand, in addition to the merit of being scientifically sound.

A "long column" is defined as one the height of which, h, is x diameters, or more; and its office is to transmit a compressive stress through the path h without relying on lateral support. If the column be subjected to increasing stresses, it begins to bend as if it were a beam supported at both ends and loaded normally to its length, and finally collapses with more or less abruptness, although the crushing stress proper to the material has not been reached.

* *Elements of Machine Design*, by Prof. W. C. Unwin, thirteenth edition, 1892, vol. i., pages 82 to 84.

Suppose a column, then, the length of which $h = xd$; testing it with gradually increasing loads, it ultimately snaps at, say, the half-height, under a load much below crushing limits. It is evident that sufficient lateral support at the half-height would have prevented collapse under the same load. The long column would, in that case, have sustained a greater load, and might, under this greater load, have collapsed at the quarter-height, or at the three-quarters-height, or at both. But sufficient lateral support at these heights, again, would prevent collapse even there: although still greater loads would produce collapse at intermediate points, such as the $\frac{1}{8}$th, $\frac{3}{8}$th, $\frac{5}{8}$th, and $\frac{7}{8}$th-heights. Continuing the investigation, the conclusion follows that if sufficient lateral support be given to the long column at x equal intervals of its length, the long column, in the technical sense, ceases to exist, but in place thereof there are x little columns, in each of which the height is equal to the diameter. The safe stress on each of these little columns is obviously equal to the safe crushing stress of the material, and each of these little columns is therefore absolutely free from risk of collapse. It is not, of course, herein implied that crushing formulæ cannot be relied on till $d = h$: it is merely desired here to depend on data of the reliability of which there can be no possible question. Consequently, in the case of long columns, the risk of collapse arises solely from the absence of lateral support. But what is the mechanical nature of that entity, the "lateral support"? It is a system of pressures properly balanced, or, rather, it is an essential part of such a system. The ideal system in, say, the case of long columns, is realized, if the forces which strive to prevent bending are equal to the forces which strive to effect the bending of the column. In that case, there would be no bending at all, and no possibility of collapse.

Now this ideal state of balance, so far as external mechanical forces are concerned, is as nearly as possible the actual position in the normal tubbing case. The perimeter being circular, every line of pressure thereon is represented by a common numerical measure. Each individual line of pressure on each individual point in the perimeter is a bending force, and each is met by another line of equal magnitude which resists the bending force exerted by the first line. In other words, all the lines of pressure are those of compressional force, and every individual line of compressional force is the lateral support of an equal line of

compressional force at right angles. The student can easily demonstrate the soundness of this view by drawing a series of figures, of which the first steps are shown below.

In the case of the long column, without lateral support, it fails by collapse at some point in its length; and with lateral support at various intervals, something very like collapse may occur at points intermediate between the points of lateral support. The case of the circular ring is strictly analogous, when the pressure is external and normal to the perimeter. Let *abab* (fig. 1, plate xxiii.) be a homogeneous ring of uniform thickness, and let it receive sufficiently severe stresses (or excesses of stress over the average stress) on two opposite points, *a* and *a*, in the circumference. Then the stresses will tend to depress the ring at *a* and *a*. But since depressions at *a* and *a* can be effected only on the condition that some other points in the ring are bulged, this bulging may be supposed to take place at *b* and *b*, and the ultimate result is the collapse of the ring. If the ring be made of some moderately pliable material, as wrought-iron, the final form of the collapsed ring may be something like that shown in fig. 2; whilst, if the ring be brittle like cast-iron, fig. 3 might represent the ring at the instant of collapse.

If, in order to supply sufficient lateral support to prevent the bulging at *b* and *b*, the pressures on those points are increased until they are equal to the pressures on *a* and *a*, then the ring will be depressed by the pressures at *b* and *b*, as well as by the pressures at *a* and *a*; but it will now bulge at *c*, *c*, *c*, and *c*, as shown in figs. 4 and 5. Thus, taking the case of the brittle metal, two opposite pressures 180 degrees apart break the ring into arcs of 90 degrees; four equal pressures on points 90 degrees apart break up the ring into arcs of 45 degrees; and so on to the end of the chapter, when, covering all the points in the ring with equal and sufficient pressures, the ring breaks up into infinitesimally small fragments. But, when the number of fragments increases to infinity, it is evident that the associated phenomena are then no longer those of collapse, but those of simple crushing. It is obvious, therefore, that whatever the depth and pitch of any stiffening ribs or flanges that may be employed, the collapsing pressure can never exceed the limits imposed by the crushing pressure. Hence, the Board of Trade lays it down as an axiom that whatever the pressure deducible from and allowable by any col-

lapse formula (even if that formula constitutes the official rule of the Board of Trade), the actual pressure shall not in any case exceed that allowed by the "limiting formula" (as it is called), which limiting formula is found, on examination, to be a simple crushing formula. This pronouncement of the Board of Trade applies to furnace-tubes, but it is manifest from what has been said that it has a general application to all tubes pressed externally.

It is perfectly clear, however, that uniform pressure all round the perimeter means lateral support all along the "long column" which the circular perimeter represents; and this particular stage may be concluded by saying that a circular tube of homogeneous material and uniform thickness, surrounded by equal pressures and equal temperatures on all points of any given perimeter, must fail, if it fails at all, by simple crushing and not by collapse.*

It appears, therefore, that in the normal tubbing case, and with the single exception of corrosion, already provided for, the usual external factors such as those which produce the collapse of an arch, or of a boiler-furnace tube, have no practical existence. Then to what purpose are the usual ribs and flanges cast on ordinary tubbing-plates? The purpose is very clear. (1) The first office of the flanges is to provide a cylinder with rigid ends. As shafts, and, therefore, tubbing rings, must be left open, the ring is a cylinder with open ends; and open ends are evidently weak ends, unless the rigidity associated naturally with closed ends is secured by other means. In the tubbing case, the necessary rigidity is secured by casting the cylinder with end-flanges. A further purpose served by the flanges is that of facilitating the accurate joining-up of the various segments and rings in a single structure, and thus more surely securing the stability (as distinct from the mere strength) of the completed column. It will be seen, therefore, apart from any question of collapse-risk in the ordinary sense, that the flanges are necessary for structural pur-

* Prof. W. C. Unwin considers the number of segments or lobes found in a collapsed tube as functions of the ratio $\frac{l}{d}$, where l is the length, and d the diameter of the tube. The writer has considered them as functions of the distribution of pressures. The difference of these two standpoints, however, is more apparent than real, since it could, if necessary, be easily shown that the distribution of the effective pressures is itself, in some measure, a quantity that depends on the value of $\frac{l}{d}$.

poses, just as flanges are necessarily cast on the various pieces of the rising main, where collapse is altogether out of the question; since, in this latter case, the strain on the tube is due to a tensile stress. (2) However, in the case of the ribs, the clear presumption is that whoever first initiated the practice of casting the segments with ribs must have had the risk of collapse present to his mind. And, indeed, it would have been curious if the grand old engineers of British mining had lived through their whole strenuous lives without ever having once apprehended the possibility of their long tubbing columns perishing by collapse. It is said, of course, that their formulæ pay no attention to the ribs and flanges. Quite so: but the design of the specimens of tubbing bequeathed by them bears silent but effective witness to the fact that these grand old men knew all about it. Therefore, they designed their long tubbing columns in precisely the same way as that in which mechanical engineers have since learned to design their long furnace-tubes in steam-boilers. They built up their long columns on the principle that the effective length divided by the effective thickness was equal to a comparatively small ratio. They might have realized this (then) new theory by increasing the effective thickness only, in which case the effective length would have been measured by the total height of a whole column of what is now called "shell" tubbing. But, instead of this, they reduced the effective length by building up the column in a series of short cylinders having rigid ends; and the effective length became straightway equal to the distance separating each pair of stiffening rings, whether such rings be called ribs or flanges.* To this end, the late Mr. Greenwell proposed his practical tubbing formula (so the writer understands) as being applicable when the height of the segments does not exceed 2 feet, with, presumably, a horizontal rib at half depth. That is to say, his formula is not guaranteed to be perfectly safe, unless the "rigid ends" are within one foot of each other. And it may be asserted without hesitation that wherever furnace-tubes in steam boilers are so designed that the ratio of effective length to effective thickness is a ratio so small as even to approximate to the value seen in ordinary tubbed shafts, no collapse formula will

* Similarly, to-day, the effective length of a furnace-tube in a steam-boiler is simply the distance between each pair of "rigid ends," whether such rigid ends be called flanges, hoops, rings, or corrugations.

apply; and, in such a case, the only safe rule for the allowable working pressure is the "limiting" formula, which is the formula of simple crushing. It must be noted, moreover, that, as compared with rings of tubbing, the furnace-tube is subjected to conditions which are immeasurably the more severe.

What, then, in the tubbing case, are the actual collapse-factors against which these ribs make provision? So far as the writer can see, there are but two of them. The first has its birth in the difficulty of securing the perfect circularity of the tubbing, although there is really no reason why the departure therefrom should be other than infinitesimal. A circle, no doubt, is a plane figure the shape of which is perfect; casting methods, on the other hand, are not perfect, but the departure from circularity during careful casting should not be so large as to make the collapse-risk appreciable. It is the concern of the practical engineer-in-charge to see that his specifications in this direction are duly adhered to by the founders. If he cannot reasonably demand perfection, he can at least insist on the minimum of error. Against the slight collapse-risk due to such a small deviation from circularity, the ordinary design of cast-iron tubbing is absolutely efficient—almost ridiculously so: it is like sending a whole regiment of soldiery against a boy throwing stones.

The other factor of possible collapse is one created by the practical engineer: it arises from improper methods which may be, and often are, employed in setting-up the tubbing. If the founders fail to secure perfect circularity in the casting of the metal, the average practical sinker may be trusted to magnify the error as much as possible in the setting-up of the various pieces in their permanent positions. Wedging the tubbing into positions which the casting imperfections object to, or which previous errors in setting-up now render untenable, is a very pretty process to watch, so long as one does not appreciate what it all means. One of the "baff-ends" wedged in behind a refractory segment may exert a local pressure greater than that ever to be sustained by any other segment in the ring, and greater, perhaps, than that which any segment in the whole column was ever designed to resist. The effect of this (especially if the interspaces between these murderous "baff-ends" be merely filled in with loose material) is to further impair the circularity of the arch at each ring, and to destroy the symmetrical arrangement

of the pressures on the column as a whole. Then comes the wedging of the various vertical joints, the wedges being driven from the inner surface of the arch: wooden wedges so long as they can be entered with the assistance of a chisel, and iron wedges afterwards until no more can be driven in. If the tubbing still stands after all these desperate attempts to unkey the whole arch, the job is complete, and is then considered satisfactory, and with apparently good reason. For one would naturally suppose that if the arch stands up against all these wedges and "baff-ends," it will thereafter stand up against anything else that may, in the future, be arrayed against it. This wedging business is about the only appreciable factor that may ultimately invite the collapse of the cast-iron arch. Such a method is not worthy of imitation in this twentieth century, and, what is more to the point, it is not a method that anyone is obliged to employ.

In order to prove the soundness of this argument, it suffices to look at the practical way in which some engineers have improved on the methods above described. For example, in the re-tubbing of the middle pit at Murton colliery,* Mr. W. O. Wood seems to have thrown all the old tubbing traditions to the four winds, clearly showing that the rule-of-thumb engineer may soon be superseded by the hitherto despised man of theory. The following are points in Mr. Wood's paper:—(1) The tubbing was specially designed to suit the conditions; (2) the metal used was of special quality and according to specification; (3) none of the usual jointing material was used; (4) the joints were machine-planed, so as to make a perfect vertical joint, and then bolted firmly together into a complete ring; (5) the ring thus formed was placed on the face-plate of a special lathe, and both horizontal flanges properly faced to gauge; (6) all these perfect fits being made in the first instance and on the surface, every separate segment and every complete ring was so numbered or marked as to come into its proper place in the shaft; and (7) in Mr. Wood's paper nothing is written about "baff-ends" or other atrocious methods of destroying the natural and necessary equilibrium of pressures on each ring, but, instead, it is stated that as each ring of tubbing was placed in position, it was rammed solid behind with cement-concrete. The above forms a summary of the details of

* "The Re-tubbing of the Middle Pit, Murton Colliery, 1903," by Mr. W. O. Wood, *Trans. Inst. M. E.*, 1904, vol. xxvii., page 197.

Mr. W. O. Wood's method of fixing the tubbing; but there are probably few engineers who have as yet adequately appreciated what an immense advance it constitutes on the older method previously described. The collapse of tubbing designed on the ordinary plan and built up on Mr. Wood's lines is absolutely out of the question, provided that the allowance for corrosion be sufficient.

Enough has been said, however, to prove that the supposed collapse-risk is, or may be made, practically non-existent. In any ordinary case, with any ordinary style of tubbing, the stiffness is sufficiently conspicuous to bring the tubbing cylinder within the jurisdiction of the "limiting" formula, and that is so because no possible stiffening can ever extend the collapsing pressure beyond the limits of the crushing pressure.

But it may be asked: Do not the pitch and depth of the ribs and flanges affect the crushing strength in its totality? Do they not add to the area of metal resisting the crushing stress? Do they not diminish the intensity of the stress? And may not therefore the safe numerical value of t_2 be taken at something less than it would be if the ribs and flanges were not there? The answer is both "yes" and "no," as there is a little fallacy here at which one may stumble into error. The ribs, etc., add to the stiffness only without adding anything to the strength of the structure. Their object is merely to impart stability or equilibrium. The rib may even affect the strength adversely, in the same way as surplus material does in other structures: the stress concentrates itself on the weakest part. On the other hand, it is certainly true that if the ribs and flanges were absent in any tubbing column of appreciable height, t_2 would require to be greater, because the want of stiffness would create a state of unstable equilibrium, and in that case, being no longer able to count upon the normal crushing strength of the material, the lesser crushing strength must be compensated by the greater area of crushing resistance in t_2. But having put on ribs, or stiffening hoops, in sufficient number to restore equilibrium, and the normal crushing strength being restored, no additional stiffening can ever justify anyone in counting upon more than that.

Therefore, it is herein concluded that, so long as tubbing plates of the ordinary design are employed, and so long as moderately careful methods of setting up are practised, the only rational

formula for t_2 is one based on the laws of simple crushing. In what follows, any idea of collapse-risk is ignored, and any idea implying that the surplus material in ribs and flanges adds to the natural crushing strength of the tubbing is also ignored as untenable.

Crushing Formula for "Thin" Cylinders.—For all structures the rational formula consistent with safety and economy alike is that the total pressure equals the total resistance. If a cylinder be one inch long and very thin, it is practically true that:—

$$pd = 2ft \quad . \quad . \quad . \quad . \quad (4)$$

where p is the pressure in pounds per square inch; f the safe stress in pounds per square inch; d, the internal diameter of the cylinder in inches; and t, the thickness of the cylinder in inches. For pd is the total pressure acting at right angles to any given diameter, and $2ft$ is the total resistance: since there are t inches of metal at each end of the given diameter, or $2t$ inches in all, each inch being capable of resisting a stress of f pounds per square inch. And, if t be very small in comparsion with d, it is not, perhaps, of practical moment whether p act on the internal or on the external surface of the cylinder, provided that f be taken as the tensile strength in the one case, and as the compressive strength in the other. Still, it is quite clear that the projected area of an internal pressure can be truly denoted only by d; and it is equally clear that the projected area of an external pressure can be truly denoted only by D, the external diameter of the cylinder. Moreover, it is just as obvious that there is no real reason why calculations in formulæ should be based upon a total pressure pd if the actual total pressure in the concrete is pD. In the tubbing case, the projected area of the pressure is always and necessarily D, yet most of the current tubbing formulæ persist in stating it as d, without any qualifying coefficient of compensation whatsoever.

But, if the tubbing cylinder be considered simply as a "thin" tube the thickness of which varies directly as the total pressure, when d is constant, its rational formula can only be written as:—

$$p\mathrm{D} = 2ft_x \quad . \quad . \quad . \quad . \quad . \quad (5)$$

and t_x will be greater than the thickness t in the equation (4) by a measurable amount.

But as D, in many cases, cannot be known until t_x is known,

the equation (5) may be reduced to terms of d. Then, if R be the external radius in inches, R equals $r+t_x$, where r is the internal radius of the cylinder, and D equals 2 R; then, by the equation (5):—

$$2ft_x = pD = 2pR = 2p(r+t_x);$$

therefore,

$$2ft_x = 2pr + 2pt_x,$$

and,

$$t_x = \frac{pr}{f-p} \quad . \quad . \quad . \quad . \quad . \quad . \quad (5a)$$

It will be noted that this is really Mr. Atkinson's formula for T, the total thickness of the tubbing. Hence Mr. Atkinson's would be a rational tubbing formula if t_1, t_2 and T were equal values. But they reduce to practically equal values, only when the tubbing is a "thin" cylinder in the technical sense, and a "thin" cylinder, moreover, not liable to corrosion by shaft-waters.

Comparing equations (4) and (5a) it will be seen that

$$\frac{t_x}{t} = \frac{f}{f-p}; \text{ and that } t_x = \frac{fl}{f-p} \quad . \quad . \quad . \quad (6)$$

Thus $\frac{f}{f-p}$ is an identity of $\frac{R}{r}$, which may be used in formulæ before the values of R and t_x are determined. (See Appendix III.)

Definition of a "Thin" Cylinder.—A "thin" cylinder is usually defined as one where t is small in comparison with d. But such a definition merely hides the indefinite quantity "thin" behind the equally indefinite quantity "small." The more practical definition of a thin cylinder is that it is one so thin that the error contained in the formula (4) is so small as not to be of practical moment. For, after all, the equation (4) does proceed on an assumption which is not absolutely sound. But, if the practical engineer is to appreciate the fact that the error is unimportant, he can do so only by first ascertaining its magnitude. And, to ascertain this, he must refer to the formulæ of so-called "thick" cylinders. But the formulæ of thick cylinders, let it be noted, are the formulæ of all cylinders, thick or thin, which are subjected to direct tensile or direct compressive strains. As a matter of fact, there are, in actual practice, no "thin" cylinders, for all have an appreciable thickness, through which the stress varies from film to film, a fact which the equations (4) and

(5) entirely ignore. Then why not refer at the outset to the case of "thick" cylinders, that is to say, to the general case of all cylinders, and have done at once and forever with such lame makeshifts as those constituted by the equations (4) and (5)?

The General Case of all Cylinders.—The rational formula has been defined as one which is consistent with the present state of knowledge. That state is not by any means perfect—far from it—but it is at least more advanced than the general and constant harking back to such rules as the equation (4) would seem to evidence. And it is simply rational to bring practice into line with the best theory, rather than to base it on any which is worse than the best.

Now, it is known (1) that the pressure being constant, the thickness of a cylinder is required to vary directly as the projected area of pressure; and (2) it is well within the present state of knowledge that, the projected area being constant, the thickness is required to vary rather faster than the intensity of the pressure. The writer desires to emphasize this second statement, since it has recently been attempted to teach that the thickness need not increase even as fast as the pressure p increases.* Just precisely how much faster t should vary than p is, as yet, a matter of some little uncertainty; but formulæ constructed on those lines (some derived from theory and some from experiment) show a remarkable measure of agreement. Four of these rules may be quoted and compared. No doubt they are a little cumbrous to manipulate, but the present writer intends to submit a practical and much more simple rule that will give the same results within limits that cover the whole of the tubbing problem. For purposes of comparison, all the formulæ will be reduced to similar symbols, namely, R, r, p, t_x, and f as already defined, f being the safe compressive stress. It is assumed that t_x and R are the unknown quantities, and that r, p, and f are known. Some of the formulæ are stated originally for an internal pressure p acting on a projected area equal to d, and these will be practically equated to the opposite case of an external pressure acting on D by putting f = a compressive stress, and $t_x = t$ multiplied by f and divided by $(f - p)$. (For direct formula, see Appendix III.)

* "The Thickness of Cast-iron Tubbing," by Mr. T. A. O'Donahue, *The Colliery Guardian*, 1905, vol. xc., page 314.

General Formula (A).—This is due to Prof. W. Steadman Aldis,* and may be stated thus:—

$$R = r \times \sqrt{\frac{f}{f-2p}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (A)$$

and, $t_x = R - r$.

General Formula (B).—This is due to Prof. Grashof, and is stated by Prof. Unwin† from the standpoint of a bursting pressure. Equating the rule to the greater area projected on D, and putting f = the compressive stress, it follows that:—

$$t_x = \frac{fr}{f-p}\left[-1_x + \sqrt{\frac{3f+2p}{3f-4p}}\right] \quad . \quad . \quad . \quad (B)$$

General Formula (C).—This is given by Prof. Andrew Jamieson,‡ and he states it as a bursting formula. Equated to the tubbing case, it becomes:—

$$\text{Log}_e\left[1 + \frac{t_x}{r}\right] = \frac{p}{f-p} \quad . \quad . \quad . \quad . \quad (C)$$

from which t_x is easily found. It will be noted that the logarithm is hyperbolic. If common logarithms are employed, the formula becomes:—

$$\text{Log}_{10}\left[1 + \frac{t_x}{r}\right] = M \times \frac{p}{f-p},$$

where $M = 0{\cdot}43429 + \ldots$ = the modulus of common logarithms.

General Formula (D).—This rule is due to Prof. Lamé, and is quoted by Prof. W. Lineham§ as an internal-pressure formula. Equating again to the external pressure, projected on the larger diameter D, the rule becomes:—

$$t_x = \frac{fr}{f-p}\left[-1 + \sqrt{\frac{f+p}{f-p}}\right] \quad . \quad . \quad . \quad . \quad (D)$$

In all these formulæ, thus stated, t_x in the general case corresponds to t_2 in the tubbing case, as per equation (3).

* "On Internal Stress in Cylindrical and Spherical Dams," by Prof. W. Steadman Aldis, *Trans. N. E. Inst.*, 1883, vol. xxxii., page 201.

† *Elements of Machine Design*, by Prof. W. C. Unwin, thirteenth edition, 1892, vol. i., page 48.

‡ *Text-book of Applied Mechanics*, by Prof. Andrew Jamieson, second edition, 1900, vol. ii., page 248.

§ *Text-book of Mechanical Engineering*, by Prof. W. Lineham, second edition, 1895, page 399.

Now, all the general formulæ, lettered above, are in remarkable agreement, as will be seen on looking at Table I., to which specific reference will presently be made. But they look rather formidable in the sight of a busy practical engineer. Hence the writer half expects to be asked whether no simpler rule can be stated. Now, whilst he is not acquainted with any simpler rule that would cover the entire general case of all cylinders, he certainly believes that a simpler formula will cover that particular portion of the general case in which the entire tubbing case is included.

A Simple Rational Formula to find t_2.—The general case covered by the formulæ, lettered from (A) to (D), probably comprizes all cases where the cylinder is subjected to a pressure p not greater than $0{\cdot}25f$. The whole of the tubbing case, on the other hand, will probably never exhibit an instance where p will exceed $0{\cdot}1f$. It seems perfectly safe to say so much; for, even with poor metal, and a large factor of safety, one-tenth of f would amount to 1,000 pounds per square inch, which is, as yet, and so far as the writer is aware, an unheard-of numerical value of p in actual practice. Assuming, then, that the tubbing case will present no instance where the pressure p is greater than one-tenth of the safe stress f, the following simple rule is rationally applicable to the entire tubbing case, so far as finding the numerical value of t_2 is concerned. Then the pressure-member of the rational tubbing formula is:—

$$t_2 = \frac{pr}{f - 1{\cdot}6p} \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

for t_2 obtained by the equation (7) is equal to t_x obtained by the equations (A) to (D), so long as p does not exceed one-tenth of f.

In Table I. are set forth: the values of t_x given by the general formulæ lettered from (A) to (D); the mean of those values; the values of t_2 given by equation (7); and the values of t_2 given by ordinary current tubbing rules, after the model of equation (4). The first column shows, in terms of f, all the typical pressures, p, met with, or likely to be met with in practice, and opposite each pressure, on the same horizontal line, are shown the various values of t_2 corresponding to that pressure, as deduced from the lettered general formulæ, the rational tubbing formula (7) and the irrational rule the type of which is equation (4). In order

to minimize the number of decimal places, whilst at the same time displaying the values to three significant figures, it has been assumed that in all cases the numerical value of r is 100 (inches), corresponding to an internal diameter of from 16 to 17 feet. If columns 6 and 7 be carefully compared, it will be seen that in no instance, from $f = 10p$ to $f = 200p$, do the results of these two columns of thicknesses differ by so much as $\frac{1}{2}$ per cent.

TABLE I.—THICKNESS OF TUBBING FOR SHAFT, 100 INCHES IN INTERNAL RADIUS.

Value of p.	Thicknesses of Tubbing by the General Formulæ of Cylinders.					Thickness of Tubbing by the Equation (7).	Thickness by the Equation 4, the Ordinary Rule.
	(A)	(B)	(C)	(D)	Mean.		
	Inches.	Inches.	Inches	Inches.	Inches.	Inches.	Inches.
$f \div 200$	0·504	0·505	0·504	0·504	0·504	0·504	0·500
$f \div 150$	0·675	0·674	0·673	0·674	0·674	0·674	0·667
$f \div 100$	1·015	1·017	1·015	1·015	1·016	1·016	1·000
$f \div 90$	1·130	1·130	1·130	1·130	1·130	1·131	1·111
$f \div 80$	1·270	1·280	1·270	1·270	1·273	1·276	1·250
$f \div 70$	1·460	1·470	1·450	1·460	1·460	1·462	1·429
$f \div 60$	1·710	1·720	1·710	1·710	1·713	1·712	1·667
$f \div 50$	2·050	2·080	2·060	2·060	2·063	2·066	2·000
$f \div 40$	2·600	2·620	2·600	2·600	2·605	2·604	2·500
$f \div 30$	3·510	3·550	3·510	3·510	3·520	3·521	3·333
$f \div 20$	5·410	5·500	5·400	5·400	5·425	5·435	5·000
$f \div 10$	11·800	2·160	1·750	11·730	11·860	11·905	10·000
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)

The Complete Rational Tubbing Formula.—One may now substitute in equation (3) the value of t_2 given by equation (7), and thus obtain the complete rational formula for T, the total effective thickness of the tubbing. Then:—

$$T = \frac{l}{n} + \frac{pr}{f - 1{\cdot}6p} \quad . \quad . \quad . \quad . \quad (8)$$

This is a rational tubbing formula, because, so far as the present state of knowledge permits, it takes into due account all the various factors of T. The numerical values of the algebraic symbols employed will vary between one case of practice and another, and these must be carefully determined by the practical engineer in charge of the local case. No theorist can rationally fill in the values beforehand. A word, however, may legitimately be added with respect to the methods by which those numerical values may be estimated.

Allowance for Casting-imperfections.—With regard to the necessary allowance for imperfections of casting, in equation

(8), T is the effective thickness required; but the apparent thickness, or the thickness to specification, must be K, and:—

$$K = T + c \quad . \quad . \quad . \quad . \quad (9)$$

where c is the casting allowance referred to. The writer calls K the "apparent" thickness, because the addition of c is merely designed to place T at par, as it were. It is generally allowed that c should be greater on thin plates, and less on the thicker plates. Thus, in the tubbing case, c should be a maximum at the top and a minimum at the bottom of the column. With the view of covering this condition, Mr. T. A. O'Donahue has proposed* that the entire apparent thickness, K, should vary only as the square root of pr, and he suggests the following as a complete tubbing rule:—

$$K = \sqrt{\frac{pr}{m}}\,(?),$$

where m is a numerical constant. Such a rule, however, ingenious as it may be, is not a rational solution. It simply obscures the essential factors of the problem, and is at best a rule-of-thumb, of which there are already too many in mining literature. As a matter of fact, the actual principles which fix the true value of this casting allowance are too obscure to be reduced to a reliable formula; and, therefore, a much better way is to be content with exercising one's ordinary engineering instincts:

(1) By minimizing, as far as practicable, the probable imperfections of the casting. To this end, the ribs of the segments should not be designed of unnecessarily large proportions, neither should they be unnecessarily numerous. It is, indeed, rather doubtful whether any stiffening at all, beyond that afforded by the flanges, is really necessary. However, be that as it may, the fact remains that any unnecessary stiffening material will accentuate casting imperfections, and simply because all surplus material is a potent factor of the unequal strains induced by unequal cooling during the casting process. Further, the surplus material being minimized as to quantity, the imperfections of the casting may be further reduced by a proper, as opposed to an improper, distribution of the surplus material. This should be distributed in such a manner that the unequal strains produced by unequal cooling shall be, to some extent, compensated rather

* "The Thickness of Cast-iron Tubbing," by Mr. T. A. O'Donahue, *The Colliery Guardian*, 1905, vol. xc., page 314.

than accentuated, by the further unequal strains induced by the pressure, p, of the shaft-waters. The pressures, p, may be equal pressures all round the tubbing ring; but the strain on the inner film of the ring, the length of which is $d\pi$, is greater than the strain on the outer film, the length of which is $\frac{R}{r}$ times as great. Thus, since the pressure, p, is uniform, the compressional strain per unit of length of the inner film of the ring is $\frac{R}{r}$ times greater than the compressional strain per unit of length of the external film. Then, since the normal pressure produces the greater compressive strain of the inner film, the engineer should distribute his surplus material on the tubbing plate so that the greater initial compressive strain of the metal shall be on the outer film; and this partial compensation of strains can only be secured when the tubbing plates are cast with inside ribs and flanges; that is to say, with the surplus material cast on their concave faces.

(2) As the maker of the tubbing naturally knows more about these matters of imperfect casting than the purchaser can be expected to know, the purchaser will further minimize such imperfections by putting the maker on the alert by reason of the guarantees exacted from him by the prospective buyer.

And, finally, the mining engineer, in each particular case of practice, will best arrive at an estimate of the proper value to be attached to c in the equation (9), by friendly consultation with the maker of the tubbing, who, as an expert, will be fairly competent to advise, and who, as a business man, will be only too pleased to give a customer the advantage of his expert counsel.

Note on the Value of p.—It is commonly supposed, and all current tubbing formulæ actually take it for granted, that $p = wh$, where w is the weight of a cubic inch of water, and h the height of the water-head in inches. In most cases, this is not quite true: in some cases, it is very far from being true. For, in most instances, if the water were not there at all, it is necessary to dam back the earth-pressure by walling the shaft; but, since the water is there as well, cast-iron tubbing is substituted for the brick-walling, and in that case, the pressure behind the dam will evidently be:—

$$p = wh + \mathrm{E} \quad . \quad . \quad . \quad . \quad (10)$$

where E is the pressure of the earth or rock, and where wh is the pressure of the water, both in pounds per square inch.

These earth-pressures, so far as they are resisted by the tubbing, are exerted horizontally, and these horizontal components of the earth-pressure may be calculated by the usual formulæ of retaining walls. If the shaft-strata are moderately firm, and the shaft of circular form, the value of E in the shaft may be rather less than the value of E on the flat retaining wall, and the formulæ referred to may thus give the value of E a little too large for the circular shaft. On the other hand, however, the very fact of the strata being moderately firm will give E a very small value for either the flat or the circular dam; and since the theoretical value of E is thus small, and the actual value also small, the difference of the theoretical and actual values will constitute an error small enough to be left out of account, especially as whatever error exists will be one on the side of safety. Hence, where the strata are moderately firm, the formulæ of flat retaining walls may be legitimately employed in the case also of the circular retaining wall or tubbing.

In the opposite case, where the strata are of a less compact nature, the circular form of the shaft, as the strata become more and more unstable, will have less and less effect in the restraining of the earth-pressure, until the semi-fluid condition is attained, as typified by wet clay, shingle, and quicksands, when the circularity will lose its restraining influence altogether. Therefore, the formulæ of retaining walls will apply more and more closely to the case of the tubbing as the shaft-strata adhere less and less firmly. Hence, the formulæ referred to will apply generally; because (1) if the strata be firm, the positive error will be small; whilst (2) if the strata be loose, the percentage error will be smaller still; and (3) because whatever small error may be made, that error will be one on the right side of safety.

The case of retaining walls was well investigated by the late Prof. Rankine,* and he gives certain rules which may be stated thus:—

If the surface of the ground be horizontal, then:

$$E = swh \frac{1-\sin \phi}{1+\sin \phi} \quad . \quad . \quad . \quad . \quad (11)$$

* *A Manual of Civil Engineering*, by Prof. W. J. M. Rankine, fifteenth edition, 1885, pages 316, 321, 396 and 401.

Or, if the surface slope at the angle of repose, then:

$$E = swh \cos \phi \quad . \quad . \quad . \quad . \quad (12)$$

Here E and w have the same values as in the equation (10), h is the head of earth or rock retained, s is the specific gravity of the material, and ϕ the angle of repose. Hence swh is the total weight of a column of earth one square inch in cross-section, and h inches high. It may be possible to find a use for the equation (12) where the strata are more or less considerably inclined; but the equation (11) will certainly apply where the shaft-strata lie horizontally or nearly so. The equations (10) and (11) may now be combined. Let H be the total head of water in inches; h, the height of the tubbing in inches, or, H, when the tubbing is open-topped; w, the weight of a cubic inch of water in pounds; s, the specific gravity of the earth or rock; and ϕ, the angle of repose, the angle being made with the horizontal line. Then assuming that the earth-pressures above the tubbing are supported by other means, the equation (10) shows that:

$$p = E + wH;$$

but by the equation (11):

$$E = swh \frac{1-\sin \phi}{1+\sin \phi};$$

and, consequently,

$$p = w \left[H + sh \frac{1-\sin \phi}{1+\sin \phi} \right] \quad . \quad . \quad . \quad (13)$$

A graphic solution of the awkward portion of this formula is demonstrated in the Appendix; see also Table IV.

An English engineer recently declared that the dimensions of tubbing adopted on the Continent "can only be characterized as absurd."* The rule just stated and the reasons advanced therefore may assist British engineers to modify their views in this direction. The real absurdity lies in the idea that the water-pressure is the only pressure that acts behind the tubbing. How can any thinking engineer suppose that, having dammed back the natural earth-pressures by walling the dry shaft, he should straightway be absolved from the same duty in tubbing the wet shaft?

It is easy to see that the true value of p may have to be calculated in sections under some circumstances, and it is neces-

* "The Thickness of Cast-iron Tubbing," by Mr. T. Campbell Futers, *The Colliery Guardian*, 1905, vol. xc., page 314.

sary to guard against calculating the same quantity twice over. In passing through a quicksand, for example, a cubic foot of the slime will contain less than a cubic foot of water and less than a cubic foot of sand, but these details can only be dealt with in each particular case by the engineer on the spot.

TABLE II.—ANGLES OF REPOSE OF VARIOUS KINDS OF LOOSE STRATA.*

Material.	Angle ϕ.	Material.	Angle ϕ.	Material.	Angle ϕ.
			(average)		
Moist earth ...	54°	Gravel ...	40°	Clay, well-drained	45°
Dry earth ...	47°	Dry sand ...	38°	Rubble ...	45°
Compact earth	50°	Sand ...	22°	Wet clay ...	16°
Vegetable earth	28°	Shingle ...	39°	—	—

It is probable that the angles of repose of the firmer strata met with in mine shafts lie between 70 and 90 degrees; but, in general, the angle is probably nearer 90 than 70 degrees. The presence of air weathers these rocks, but the presence of moisture may have contrary effects, accordingly as it is present in smaller or larger measure. Prof. Rankine has said that "the presence of moisture in earth to an extent just sufficient to expel the air from its crevices, seems to increase its co-efficient of friction slightly; but any additional moisture acts like an unguent in diminishing friction, and tends to reduce the earth to a semi-fluid condition, or to the state of mud. In this state, although it has some cohesion, or viscidity, which resists rapid alteration of form, it has no frictional stability; and its co-efficient of friction, and angle of repose, are each of them null."† One might easily imagine that Prof. Rankine was talking to a class of mining students; and that one had just caught this fine teacher impressing on their minds and memories the nature of the pressures to be kept in view when tubbing through quicksands.

Note on the Value of f.—If the older methods have often been guilty of assigning too small a value to p, it is certainly true that they have largely compensated that error by the opposite error of assigning an extravagant value to the factor of safety; but if there are any instances at all where a low factor of safety might

* *Pocket-book of Engineering Formulæ*, by Sir Guilford Molesworth, twenty-third edition, 1896, page 80.

† *A Manual of Civil Engineering*, by Prof. W. J. M. Rankine, fifteenth edition, 1885, page 316.

be legitimately adopted, the tubbing case is one of them, provided, of course, that the other co-efficients of t_2 in formulæ can be estimated with approximate accuracy. There are two reasons why this is so:—

(1) The load on the tubbing in any average case is a dead load, and a load uniformly distributed. Consequently, if one may judge by engineering practice under similar conditions, it would appear that there is no sound reason why the factor of safety should exceed 4 or 5; and probably its true value in tubbing cases has often been less than that, although its apparent value may have been twice as much, owing to the under-estimation of the pressure p and of the corrosion allowance t_1, the neglect of the casting imperfections, and the absolute ignoring of the variation of stress from film to film of the cylinder-thickness. All of these errors are inseparable from the use of the current tubbing formulæ, and all of them could only be compensated by adopting an apparently large factor of safety. But if, in the twentieth century, the various quantities can be more accurately estimated, then so large an insurance against error need no longer be maintained.

(2) It may be noted that when a numerical value is assigned to f in the equation (8), a final, and not an initial, factor of safety is then and there adopted. In almost every other kind of structure the case is different. A machine is built, say, or a rising main, and at first a factor of safety is adopted amounting to perhaps 10. As years roll on, the machine wears down, or the rising main corrodes away, until the actual factor of safety is gradually reduced from its initial value of 10 to a final value so small that the structure becomes unsafe, and has to be renewed. In the machine, or the rising main, therefore, the nominal factor of safety is the initial factor at the beginning. In the tubbing case, on the other hand, the nominal factor of safety is the final factor existing at the end of the mine's life of l years. If the corrosion-member l/n be appreciable (and after Mr. Hodges' revelations the corrosion-allowances are likely to be much greater in future than they have been in the past), it is necessary to start with an initial factor of safety, M, greater than the nominal factor, Q/f, which appears in the formulæ, where Q is the ultimate crushing strength of the metal, and f the estimated safe stress.

By transposing the equation (7), the safe stress of the formulæ is found to be:—

$$f = p\left[\frac{r}{t_2} + 1{\cdot}6\right] \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

This is the nominal safe stress of the formulæ, but it is only reached in practice after l years, when the total effective thickness, T, with which the tubbing started has been worn down by corrosion to an effective thickness equal to the pressure-member, t_2; f is essentially the final stress on the tubbing at the winding-up of the concern as a commercial undertaking.

TABLE III.—SHOWING HOW THE ACTUAL FACTOR OF SAFETY GRADUALLY DIMINISHES THROUGHOUT THE LIFE, l, OF THE MINE, AND YET IS ALWAYS GREATER THAN THE NOMINAL FACTOR APPEARING IN FORMULÆ.

Assumed Thicknesses of New Tubbing at Various Depths of the Shaft.			Actual Stress on the New Tubbing.	Estimated Stress after Time, l.	Initial Factor of Safety.	Final Factor of Safety.
Corrosion Allowance. $\left(t_1 = \frac{l}{n}\right)$	Pressure Allowance. t_2	Total Effective Thickness. T	f_o	f	$\frac{Q}{f_o} = M$	$\frac{Q}{f} = m$
Inches.	Inches.	Inches.	Pounds per square inch.	Pounds per square inch.		
1·0	0·5	1·5	5,400	16,000	14·8	5
1·0	1·0	2·0	8,300	16,000	9·8	5
1·0	1·5	2·5	9,800	16,000	8·2	5
1·0	2·0	3·0	10,800	16,000	7·4	5
1·0	2·5	3·5	11,600	16,000	6·9	5
1·0	3·0	4·0	12,200	16,000	6·6	5
(1)	(2)	(3)	(4)	(5)	(6)	(7)

N.B.—This table assumes that the diameter of the shaft is 16 feet; that the ultimate crushing strength, Q, of the metal is 80,000 pounds per square inch; that the tubbing has been designed on the lines that the factor of safety is 5; and that f in the formula (8) is consequently 16,000 pounds per square inch: f_o being the actual stress on the new tubbing.

At the commencement of operations, the total load on the tubbing is met by the whole area of the total effective thickness, T. The intensity of the stress, therefore, is not yet equal to f, but is only equal to f_o; where:—

$$f_o = p\left[\frac{r}{T} + 1{\cdot}6\right] \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

If the nominal, which is the final, factor of safety be m, the initial factor of safety is M; and since the factor of safety varies inversely as the stress on the structure, it follows that:—

$$\frac{M}{m} = \frac{f}{f_o} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (16)$$

At the end of l years, the mine will be abandoned, together with

a structure capable of sustaining the stress, f, with a margin of safety denoted by the safety-factor, m, employed in the original formula of design. In order to illustrate this aspect of the case, an arithmetical portraiture of the lessons of the equations, (14), (15), and (16), is presented in Table III., which may be left to speak for itself.

Therefore: It is suggested that a low factor of safety, Q/f, and a moderately high stress, f, may be legitimately employed when designing the tubbing for average cases: (1) Because the nature of the load does not by any means demand a high value for m. And (2) because during the entire life, l, of the tubbed shaft, the actual stress on the tubbing metal is less than the stress, f, of the formulæ; always provided that the numerical values of the co-efficients of f in the formulæ have been estimated with a reasonably close approach to accuracy.

TABLE IV.—VALUES OF THE TRIGONOMETRICAL EXPRESSION IN EQUATION (13). VALUES TAKEN FROM SLIDE-RULE, AND, IN ORDER TO MINIMISE DECIMALS, STATED 1,000 TIMES TOO LARGE. TRUE VALUE = TABULAR VALUE DIVIDED BY 1,000.

Angle of Repose denoted by ϕ.	Value of $\frac{1-\sin\phi}{1+\sin\phi} \times 1{,}000$.	Angle of Repose denoted by ϕ.	Value of $\frac{1-\sin\phi}{1+\sin\phi} \times 1{,}000$.
Degrees.		Degrees.	
0	1,000	46	163·000
2	933	48	147·000
4	870	50	132·000
6	810	52	118·000
8	755	54	106·000
10	704	56	93·600
12	656	58	82·400
14	610	60	71·800
16	569	62	62·000
18	529	64	53·400
20	490	66	45·400
22	456	68	37·600
24	421	70	31·000
26	391	72	25·000
28	361	74	19·900
30	333	76	15·100
32	307	78	11·000
34	283	80	7·660
36	260	82	4·890
38	238	84	2·750
40	217	86	1·220
42	198	88	0·305
44	180	90	0·000

N.B.—The above table may contain errors less than, say, one per cent., like all other slide-rule computations.

There are one or two other matters upon which the writer would have liked to touch, but the paper has already run to inordinate length; and he can only hope that the members will raise any neglected points during the hoped-for discussion on this paper now concluded.

APPENDIX I.—GRAPHIC SOLUTION OF THE SECOND MEMBER, WITHIN BRACKETS, OF THE FORMULA (13).

With centre O and radius sh in formula and OA in diagram (fig. 6, plate xxiii.) draw the large circle, ADBC. Draw the vertical diameter, AB, and intersect it with the horizontal diameter, CD. With a protractor, lay out the angle of repose, EOC equal to ϕ in the formula, cutting the large circle in E. From E draw the chord, EF, parallel to the horizontal diameter, CD, and cutting the vertical diameter, AB, in G. With the centre, G, and radius, AG, describe the smaller circle, AMN, cutting the chord, EF, in M. Join MB. The line MB cuts the horizontal diameter in H. Measure the distance of H from the centre O: its measure being OH. Then, in the diagram :—

$$\text{OH} = sh \frac{1 - \sin \phi}{1 + \sin \phi}.$$

APPENDIX II.—CORROSIVE ENERGY.

Mr. Isaac Hodges has recently stated* that "in his case, tubbing $1\frac{1}{4}$ inches thick had diminished in thickness to $\frac{7}{16}$ inch after a usage of about half-a-century." It thus appears that the corrosive energy of the waters, etc., at Methley Junction Colliery is much greater than that which the present writer was able to deduce from the less definite data furnished in Mr. Hodges' original paper already referred to in the text. Under such circumstances, it is of interest to note that the value of n in formula (8) would be 47, and the minimum thickness of tubbing designed to last a century would be $2\frac{1}{8}$ inches, in addition to the thickness required to resist the pressure proper throughout the entire life l of the mine. This cannot be gainsaid; for a diminution from $1\frac{1}{4}$ inches to $\frac{7}{16}$ inch, spread over 50 years, is a diminution which proceeds at the mean rate of $\frac{1}{14}$ inch per annum. Nothing could show more effectively the utter irrationality of the current formulæ, with their arbitrary numerical constants of $\frac{1}{4}$ and $\frac{1}{2}$ inch to cover corrosion, irrespective of the character of the water and the estimated length of the mine's life.

APPENDIX III.—INDEPENDENT INVESTIGATION, WITHOUT THE USE OF THE CALCULUS, OF A GENERAL RATIONAL FORMULA FOR ALL CYLINDERS AND SPHERICAL STRUCTURES UNDER PRESSURE IN THE RADIAL LINE.

To save space and labour, a pressure which acts upon the external curved surface of a cylinder and that which acts on the internal curved surface, may be distinguished as "convergent" and "divergent" pressures respectively. Formula (7) in the text is a rational formula within the limits of the tubbing case only. It

* *Trans. Inst. M. E.*, 1907, vol. xxxiii., page 123.

a structure capable of sustaining the stress, ,:" (*b*) when the
of safety denoted by the safety-factor, p is not less than 10.
original formula of design. In order , mean of the formulæ,
of the case, an arithmetical portrai ominent authorities, who
equations, (14), (15), and (16), is p s—a branch of mathematics.
may be left to speak for itself. nan. It is desirable that the
be stated in plainer terms, and
Therefore: It is suggest eer may be unacquainted with the
and a moderately high st th the theory of wedges. He may
when designing the tu derstand its properties, without under-
nature of the load d tegration. And if so, he can easily grasp and
for m. And (2) , *cal rational* theory of stress in cylinders, and thereafter dispense
shaft, the actr *formulæ in this connection.*
stress, f, of *plate xxiii.)* represent an imaginary cylinder. If solid, its half—
values of *RAK may be subdivided into a number of sectoral areas, AOB and BOC—*
with p *evidently transverse sections of wedges, whose cutting edges lie along*
section of the cylinder. The length of each wedge is equal to the radius of the
solid cylinder. If the cylinder be not solid, but hollow, its half-section will be
that of the annulus RaK'e. Its constituent parts may be represented by frustums,
such as afch, hcde, etc., the frustums of the wedges, AOB, BOC, etc., in the
solid cylinder.

Ta

If the pressure be convergent, its effect is to drive all these frustums toward the centre O. The wedging effect of the frustum, *afch*, will be as marked as that *of the completed wedge, aOh,* since the complement *fOe* is already free and serving *no purpose.* Hence the frustums which make up the hollow cylinder are true *wedges in all respects, except that of name.* Then the tendency of the convergent *pressure* being to drive all these frustums home, a compressive force is set up which actually reduces the inner and outer diameters of the cylinder. It is immaterial that the reduction is small. The vital point to be realized is that it is sufficient to signify a strain in the structure, strain being defined as the deformation produced by stress; and one cannot admit strain without also admitting deformation.

The character of the strain depends on the character of the force producing it. The force here acting is a wedging force, and one peculiarity of the wedge is that it transmits the force at right angles to the line of its own motion. The line of its motion, due to the pressure, is along the radius of the cylinder. Any line (in a plane-circle) at right angles to a radius is a tangent, and hence the compression produced in a cylinder by a convergent pressure is called the "tangential compression." And, as the frustum has one free end in the radial line and no free face in the tangential line, it is clear that the tangential stress is by far the greater portion of the entire stress. It is, therefore, only necessary to take into account the tangential strains, since adequate provision for the principal strain must necessarily cover the inferior strain also. It is by a parity of reasoning that, in designing a steam-boiler, the engineer takes only one class of seams into account.

It must be a necessary assumption in this enquiry that the whole cylindrical structure is a homogeneous body. If its homogeneity be doubtful, that suspicion can only find expression in the numerical value assigned to the factor of safety. Then the homogeneity being assumed, each constituent frustum must take up, in the compression of its own body, the whole of the pressure that it receives from without. For the tangential pressure of each frustum is met by that of the next, and

is no extraneous body to which such pressure might be transmitted. So much clear from fig. 8 (plate xxiii.) where the whole number of frustums in the are conceived of as forming the large frustum, ABCD, which is afterwards d upon itself until it again forms the cylinder EFG. From this illustra- bvious that the cylinder as a whole must take up the entire pression of its own body. And since, by hypothesis, the structure is it follows that each constituent frustum must take up its own share n the same way. Therefore it is clear that the strain produced in ie true type of that produced in the complete cylinder. Hence ider may be considered as the case of a single frustum which is essure and cannot propagate that pressure, in any effective sense, its own body. In such a case, the "useful effect" (so to speak) of the ire pressure will be completely measured by the strains produced in the frustum.

As the simplest method of obtaining a sufficiently open scale, let the given inder be very thick, as in fig. 9 (plate xxiii.). Let r equal 3, and R equal 6 ts. Let it be supposed that the entire pressure, for the time being, is concen- ted on the single frustum, ABCD. The condition is that the single frustum must ect the entire pressure in the compression of its own body. As no strain can be nslated to the remainder of the structure, that remainder may be considered as olutely incompressible. Before the pressure is applied (and understanding the ires as ratios only), the thickness of the frustum at R will be AB, and at r it l be CD. AB equals 6, CD equals 3, and at intermediate points, equally spaced. thicknesses are 4 and 5 units respectively. Let the concentrated pressure now ve in the frustum to a distance of 1 unit, as set out in fig. 10 (plate xxiii.). sults: the thickness, which was originally 6, is reduced to 5 units, that which was now only 4 units, and that which was 4 is diminished to 3 units. (The thickness ich was originally 3, is unaltered in the diagram, which would not be the case in concrete instance, but this difference does not affect the argument in any way.)

It may be noted (a) that the compressions at the various radii are, in the itive sense, equal. For $6-5=5-4=4-3=1$ unit in each case. But it should noted (b) that the strains are unequal. For the strain equals the diminution of ckness divided by the original thickness. Hence the order of the strains is as ows: $\frac{1}{6}$, $\frac{1}{5}$, and $\frac{1}{4}$. The character of the strain in the frustum, and, therefore, of t in the cylinder, is now manifest. In any homogeneous cylinder subjected to, niform convergent pressure, the strains at the various radii vary inversely as se radii. Thus the strain at the inner radius is a maximum, and that at the ernal radius a minimum. The minimum strain of the series is thus proportional $\frac{1}{R}$ and the maximum is proportional to $\frac{1}{r}$.

If the pressure is a bursting or divergent pressure, the strains produced are sile strains, and the projected area upon which the pressure acts is less than in case of the convergent pressure. But the distribution of stress is the same in h cases. The maximum strain occurs at the least radius and the minimum at greatest radius, as before. For the action is now that of a lever whose total gth is R, the pressure being uniformly distributed over a portion of length al to r, the remainder $(R-r)$ of the total length R being fixed in the cylinder ckness. The prising of the lever R by the pressure on r tends to tear open the inder, from A to D and from B to C, as shown in fig. 11 (plate xxiii.). The pressures rted at A and D may be equal in magnitude though opposite in direction, but n so, the stress at D acts on a film of metal which is $\frac{R}{r}$ times longer than the film

applies rationally (*a*) when the cylinder has efficient "rigid ends;" (*b*) when the pressure is convergent; and (*c*) when the numerical value of $\frac{f}{p}$ is not less than 10.

Within these limits, it is a practical and convenient mean of the formulæ, (A) to (D). These in turn are quoted or deduced from prominent authorities, who arrive at their formulæ by the assistance of the calculus—a branch of mathematics, unfortunately, not familiar to the average practical man. It is desirable that the theory of stress in cylindrical structures should be stated in plainer terms, and illustrated by more familiar methods. An engineer may be unacquainted with the calculus, and, at the same time familiar with the theory of wedges. He may construct a rectangular hyperbola and understand its properties, without understanding the mystic sign $\int$ of integration. And if so, he can easily grasp and appreciate the general rational theory of stress in cylinders, and thereafter dispense with make-shift formulæ in this connection.

Let fig. 7 (plate xxiii.) represent an imaginary cylinder. If solid, its half-section RAR'O may be subdivided into a number of sectoral areas, AOB and BOC. Such areas are evidently transverse sections of wedges, whose cutting edges lie along the axis of the cylinder. The length of each wedge is equal to the radius of the solid cylinder. If the cylinder be not solid, but hollow, its half-section will be that of the annulus R*a*R'*e*. Its constituent parts may be represented by frustums, such as *afeb*, *bedc*, etc., the frustums of the wedges, AOB, BOC, etc., in the solid cylinder.

If the pressure be convergent, its effect is to drive all these frustums toward the centre O. The wedging effect of the frustum, *afeb*, will be as marked as that of the completed wedge, *a*O*b*, since the complement *f*O*e* is already free and serving no purpose. Hence the frustums which make up the hollow cylinder are true wedges in all respects, except that of name. Then the tendency of the convergent pressure being to drive all these frustums home, a compressive force is set up which actually reduces the inner and outer diameters of the cylinder. It is immaterial that the reduction is small. The vital point to be realized is that it is sufficient to signify a strain in the structure, strain being defined as the deformation produced by stress; and one cannot admit strain without also admitting deformation.

The character of the strain depends on the character of the force producing it. The force here acting is a wedging force, and one peculiarity of the wedge is that it transmits the force at right angles to the line of its own motion. The line of its motion, due to the pressure, is along the radius of the cylinder. Any line (in a plane-circle) at right angles to a radius is a tangent, and hence the compression produced in a cylinder by a convergent pressure is called the "tangential compression." And, as the frustum has one free end in the radial line and no free face in the tangential line, it is clear that the tangential stress is by far the greater portion of the entire stress. It is, therefore, only necessary to take into account the tangential strains, since adequate provision for the principal strain must necessarily cover the inferior strain also. It is by a parity of reasoning that, in designing a steam-boiler, the engineer takes only one class of seams into account.

It must be a necessary assumption in this enquiry that the whole cylindrical structure is a homogeneous body. If its homogeneity be doubtful, that suspicion can only find expression in the numerical value assigned to the factor of safety. Then the homogeneity being assumed, each constituent frustum must take up, in the compression of its own body, the whole of the pressure that it receives from without. For the tangential pressure of each frustum is met by that of the next, and

there is no extraneous body to which such pressure might be transmitted. So much will be clear from fig. 8 (plate xxiii.) where the whole number of frustums in the cylinder are conceived of as forming the large frustum, ABCD, which is afterwards bent round upon itself until it again forms the cylinder EFG. From this illustration, it is obvious that the cylinder as a whole must take up the entire pressure in the compression of its own body. And since, by hypothesis, the structure is homogeneous, it follows that each constituent frustum must take up its own share of the pressure in the same way. Therefore it is clear that the strain produced in the frustum is the true type of that produced in the complete cylinder. Hence the case of the cylinder may be considered as the case of a single frustum which is driven in by pressure and cannot propagate that pressure, in any effective sense, beyond its own body. In such a case, the "useful effect" (so to speak) of the entire pressure will be completely measured by the strains produced in the frustum.

As the simplest method of obtaining a sufficiently open scale, let the given cylinder be very thick, as in fig. 9 (plate xxiii.). Let r equal 3, and R equal 6 units. Let it be supposed that the entire pressure, for the time being, is concentrated on the single frustum, ABCD. The condition is that the single frustum must reflect the entire pressure in the compression of its own body. As no strain can be translated to the remainder of the structure, that remainder may be considered as absolutely incompressible. Before the pressure is applied (and understanding the figures as ratios only), the thickness of the frustum at R will be AB, and at r it will be CD. AB equals 6, CD equals 3, and at intermediate points, equally spaced. the thicknesses are 4 and 5 units respectively. Let the concentrated pressure now drive in the frustum to a distance of 1 unit, as set out in fig. 10 (plate xxiii.). Results: the thickness, which was originally 6, is reduced to 5 units, that which was 5 is now only 4 units, and that which was 4 is diminished to 3 units. (The thickness which was originally 3, is unaltered in the diagram, which would not be the case in the concrete instance, but this difference does not affect the argument in any way.)

It may be noted (a) that the compressions at the various radii are, in the positive sense, equal. For $6-5=5-4=4-3=1$ unit in each case. But it should be noted (b) that the strains are unequal. For the strain equals the diminution of thickness divided by the original thickness. Hence the order of the strains is as follows: $\frac{1}{6}$, $\frac{1}{5}$, and $\frac{1}{4}$. The character of the strain in the frustum, and, therefore, of that in the cylinder, is now manifest. In any homogeneous cylinder subjected to a uniform convergent pressure, the strains at the various radii vary inversely as those radii. Thus the strain at the inner radius is a maximum, and that at the external radius a minimum. The minimum strain of the series is thus proportional to $\frac{1}{R}$ and the maximum is proportional to $\frac{1}{r}$.

If the pressure is a bursting or divergent pressure, the strains produced are tensile strains, and the projected area upon which the pressure acts is less than in the case of the convergent pressure. But the distribution of stress is the same in both cases. The maximum strain occurs at the least radius and the minimum at the greatest radius, as before. For the action is now that of a lever whose total length is R, the pressure being uniformly distributed over a portion of length equal to r, the remainder $(R-r)$ of the total length R being fixed in the cylinder thickness. The prising of the lever R by the pressure on r tends to tear open the cylinder, from A to D and from B to C, as shown in fig. 11 (plate xxiii.). The pressures exerted at A and D may be equal in magnitude though opposite in direction, but even so, the stress at D acts on a film of metal which is $\frac{R}{r}$ times longer than the film

receiving an equal pressure at A. Hence, since the stress at D is distributed through R/r times the material, the intensity of the stress is only r/R of the intensity at r. From which the general law of strains in a cylinder under pressure is evident. Whether the pressure be divergent, as in the case of a rising main, or whether it be convergent, as in the case of cylindrical dams and tubbing, the law holds good: namely, the strains in all films of the cylinder-thickness vary inversely as the distances of those films from the axis of the cylinder; or, shortly, the strains vary inversely as the radii at which they occur.

Now, since the strains at r_1, r_2, r_3, etc., vary as $\frac{1}{r_1}$, $\frac{1}{r_2}$, $\frac{1}{r_3}$, etc., it will be evident to all engineers familiar with the principle of the indicator diagram, that the various strains arrange themselves as the vertical ordinates to a hyperbolic curve, such as that of the rectangular hyperbola shown in fig. 12 (plate xxiii.). At the radius r equals OA, the strain is Af; at the radius R equals OX, the strain is Xm: and at all intermediate radii, such as OB, OC, OD, etc., the strain at any given film of the thickness is proportional to the vertical ordinate meeting the line of that film where it abuts on the horizontal asymptote, OX. The constant product of the co-ordinates to any given point on the curve is equal to OA by OY, equals the minimum radius r multiplied by the maximum stress f on the unit-area.

The total stress on the radial line equals the sum of the stresses at all the radii, equals the hyperbolic area, Afm X. The total stress on the diametral line is, of course, twice as much, but in this enquiry it is convenient to consider the projected area as a radius rather than as a diameter, and the ratios will not be affected thereby.

From their knowledge of the indicator-diagram and its formulæ, all engineers know perfectly well, without calling in the aid of the calculus, that the hyperbolic area equals the rectangular area multiplied by the hyperbolic logarithm of the ratio of expansion. In the present enquiry it is sufficient to replace this logarithm by that of the ratio of the greatest to the least radius of the cylinder. In both cases alike the logarithm required is that of $\frac{\text{OX}}{\text{OA}}$. Then:

$$\text{The hyperbolic area} = \text{OA} \times \text{OY} \times \text{Log}_e \frac{\text{OX}}{\text{OA}}.$$

Translating these geometrical quantities into algebraical symbols, if h be the hyperbolic area: r equals OA, f equals OY, and R equals OX. Then the total stress is:—

$$h = rf \text{ Log}_e \frac{\text{R}}{r}.$$

But the total stress, h, equals the total pressure, pA; where A is the projected area of the pressure on the quadrant. Thus, if the pressure be convergent, A equals R; but, if the pressure be divergent, A equals r. Then, since h equals pA, it follows that:

$$p\text{A} = rf \text{ Log}_e \frac{\text{R}}{r}.$$

Therefore:

$$\text{Log}_e \frac{\text{R}}{r} = \frac{pA}{fr}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(E)}$$

This is the rational formula for all cylinders under pressure, no matter whether such pressure be a bursting or a crushing pressure. For the cylinder, therefore, there are two cases.

(1) *Cylinders subject to Internal Pressure.*—This is the case of rising mains. Here the projected area, A equals r, and f is the safe tensile stress of the metal.

Substituting these values in the formula (E), it follows that:

$$\text{Log}_e \frac{R}{r} = \frac{p}{f}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (F)$$

This is exactly the same rule as that deduced, by the method of the calculus, by Prof. Jamieson, for hydraulic cylinders. The manner of using the rule may be shown by an example.

Example.—A small quantity of water made in a deep mine is forced direct to the surface by a ram-pump at the bottom. The pressure p at the bottom is 800 pounds per square inch; and the pipe is of good cast-iron, 5 inches in internal diameter. What should be the thickness of the bottom set?

Answer.—Since the stress is a tensile one, and the load is a live one, it will not be wise to take the safe stress at more than 2,000 pounds per square inch. Substituting the values of p and f in the formula (F), it follows that:

$$\text{Log}_e \frac{R}{r} = \frac{800}{2000} = 0{\cdot}4 = \text{Log}_e\, 1{\cdot}492.$$

The value of $\frac{R}{r}$ will be 1·492, and since d equals 5 and r equals 2½, R equals 2½ by 1·492, and

$$t = 2\tfrac{1}{2} \times 0{\cdot}492 = 1{\cdot}23 = 1\tfrac{1}{4} \text{ inches.}$$

For the same values of f and p, the formula for "thin" cylinders usually employed would give the value of t as 1 inch only—an error of about 20 per cent. on the wrong side, so far as the safety of the arrangement is concerned.

(2) *Cylinders subject to External Pressure.*—This is the case of cylindrical dams and of rings of tubbing. Here f is the safe crushing stress, and the projected area A equals R. Substituting this value of A in formula (E), it follows that:

$$\text{Log}_e \frac{R}{r} = \frac{pR}{fr} \quad . \quad . \quad . \quad . \quad . \quad (G)$$

The formula now presented appears rather awkward, since the unknown quantity appears on both sides in different forms. But these forms have a distinct numerical ratio, and the equation can be solved by observing it. Equation (G) may evidently be transposed thus: $\frac{R}{r}$ equals $\frac{f}{p}$ $\text{Log}_e \frac{R}{r}$; and the equation is solved for $\frac{R}{r}$ simply, by finding in the tables a number which is $\frac{f}{p}$ times as great as the logarithm which represents it.

Example.—A cylindrical dam is required to resist a pressure of 400 pounds per square inch. It is proposed to build the dam of oaken balks formed into wedge-frustums and laid in radial lines. If the safe crushing stress of the oak resisting this dead load be 1,200 pounds per square inch, what would be the proper value of $\frac{R}{r}$?

Answer.—The numerical value of the ratio must be $\frac{f}{p}$ equals $\frac{1{,}200}{400}$ equals 3 times the numerical value of its logarithm, hence: $\frac{R}{r}$ divided by $\text{Log}_e \frac{R}{r}$ equals 3. Looking in the tables, it is found that the logarithm of 1·86 is 0·62058 and that of 1·85 is 0·61519. Hence 1·85 is rather too small and 1·86 is rather too large, and the true value of $\frac{R}{r}$ lies between those numbers. But the difference of those numbers is very small, the difference of either from the exact value is

smaller still, and it may be assumed that $\frac{R}{r}$ equals 1·86. The dam can be built to any radius or radii found convenient, but the ratio of R to r must be 1·86 in any event. In other words, the length of the tapered balks, which forms the thickness of the dam, must be 0·86r. If the balks be 10 feet long, then 10 equals 0·86r, and r equals 11·63 feet; and the internal curve may be drawn to that radius, or to one rather less, but not to any greater radius than that.

It will be observed that the formula (C) in the paper is not quite identical with the true formula (G) last given. But the formula (C) is merely an adaptation from Prof. Jamieson's rule for internal pressure. The adaptation proceeds on the assumption that the maximum stress in the convergent case exceeds the maximum in the divergent case, in the same ratio as the mean stresses vary, which is not quite true. But within the limits of the tubbing case proper it is practically true; and the formula (C) applied within those limits will give the same results, practically, as those yielded by the formula (G). Hence, since the formula (C) is more convenient than the formula (G), it may be used for the tubbing case with advantage in that respect, and without appreciable loss in the respect of accuracy.

Maximum Value of the Allowable Pressure.—When the pressure is internal, the projected area is r and the pressure is p. The maximum stress is f, and it is the stress at r only. Hence, when the pressure is internal, the area of the maximum stress and the area of the pressure increase or diminish at the same rate as r. If r be constant, the area of pressure and of maximum stress is constant and, by the formula (F) p equals $f \operatorname{Log}_e \frac{R}{r}$. But the maximum stress cannot rationally exceed the safe stress, and that is a constant for the same material. Hence, when the pressure is internal, p varies as $\operatorname{Log}_e \frac{R}{r}$; and p may be increased as long as the logarithm can be increased. That is to say, p may be increased indefinitely.

But, when the pressure is external, the area of pressure is R and that of f is only r. Let r be constant, then fr will also be constant if f is not to exceed the safe stress. If p be increased, R must be increased also; hence the intensity of the pressure and the area of pressure increase together, and since fr is constant, it would appear that the product of p and R cannot be increased indefinitely. The formula (G) shows the limit of p in terms of f. Let the natural number $\frac{R}{r}$ equal n and let its hyperbolic logarithm be h; then from the formula (G), it follows that n equals $\frac{fh}{p}$. Now, there is no natural number n, which is less than e times the value of its logarithm to the base e; and, therefore, it follows that there is no rational value of $\frac{f}{p}$, which is less than e. Hence, the pressure being external, the minimum value of $\frac{f}{p}$ equals e; and the

maximum value of $p = \frac{f}{e} = \frac{f}{2{\cdot}718 + \ldots}$ . . . . . (H)

The value of e is incommensurable, but stated to 10 significant figures, e equals 2·718281828. The practical maximum of p is reached, however, much sooner, say when p equals $\frac{1}{3}f$. Above that value, very small increases in p necessitate exorbitant increases in the thickness of the dam. For example, the thickness required when p equals $\frac{1}{3}f$ is double that required when p equals $\frac{1}{4}f$. In this particular

case, an increase of 32 per cent. in the pressure involves an increase of 100 per cent. in the thickness of the dam and an increase of no less than 135 per cent. of the materials of construction. Hence it may be, in many cases, that a cast-iron dam may be cheaper than a wooden dam, for the simple reason that $\frac{p}{f}$ in the one case will be a much smaller value than $\frac{p}{f}$ in the other. Large values of $\frac{p}{f}$ are values which are unduly costly by reason of the increasing rapidity of the rate at which the value of $\frac{R}{r}$ progresses as the value of $\frac{f}{p}$ slowly approaches to its minimum value denoted by e. In practice, it may therefore be taken that, when the pressure is external, the minimum value of $\frac{f}{p}$ is about 4, which corresponds to a maximum value of $\frac{R}{r}$, a little less than 1·43, which is but little more than the square root of 2. Hence, an easily remembered rule may be formulated thus: In cylinders subject to an external series of converging pressures, the practical

$$\text{maximum value of } \frac{R}{r} = \sqrt{2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(J)}$$

and the

$$\text{practical maximum value of } p = \frac{f}{4} \quad . \quad . \quad . \quad . \quad . \quad \text{(K)}$$

If the proposed material of which a dam is to be constructed should require a departure from the principles of formulæ (J) and (K), it may then be considered whether another kind of material showing a greater value of f should not be employed.

Approximate Rules.—If it be desired to dispense with the use of logarithms, it may be remarked (a), that up to p equals $\frac{1}{4}f$, the equation (7) in the paper will give results within 1 per cent. of the true value of $\frac{R}{r}$ as found by the equation (G). But 1 per cent. in the value of $\frac{R}{r}$ means 3 or 4 per cent. difference in the value of t. This, however, would be the maximum error when $\frac{R}{r}$ equals the square root of 2. At less values the error would be less.

Another approximation may be made as follows: The projected area of the convergent pressure is R, and a is the mean stress. It is known that a equals $\frac{pR}{t}$. But the maximum stress is f varying as $\frac{1}{r}$, the minimum is, say m, varying as $\frac{1}{R}$. These reciprocals are the end-ordinates in the stress-diagram, fig. 12 (plate xxiii.). The approximate value of the mean ordinate is equal to half the sum of the end-ordinates. Then f is the initial ordinate, $\frac{1}{r}$; m, the terminal ordinate, $\frac{1}{R}$; and a, the mean ordinate, $\frac{1}{2}\left(\frac{1}{r} + \frac{1}{R}\right)$. Therefore:

$$\frac{f}{a} = \frac{1}{r} + \left(\frac{1}{2r} + \frac{1}{2R}\right) = \frac{2R}{R + r}.$$

Hence, on the false assumption that the mean ordinate is equal to half the sum of the terminal ordinates:

$$f = a \times \frac{2R}{R+r}.$$

But $$a = \frac{pR}{t} = \frac{pR}{R-r},$$

and substituting this value of a in the previous expression, it follows that:

$$f = \frac{pR}{R-r} \times \frac{2R}{R+r} = \frac{2pR^2}{R^2-r^2}.$$

Whence, by transposition, inversion, and division by R^2:—

$$\frac{2p}{f} = 1 - \frac{r^2}{R^2},$$

from which $$\frac{2p}{f} - 1 = -\frac{r^2}{R^2}.$$

Finally, changing the signs of every term, and extracting the square root of each side, after inversion, we obtain:

$$\frac{R}{r} = \sqrt{\frac{f}{f-2p}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (A)$$

This is Prof. Aldis' formula for cylindrical dams and tubbing, already quoted in the paper. It is thus seen that the formula (A) is but an approximation to the rational formula, notwithstanding the fact that its author evolved it by the ponderous machinery of the integral calculus. It is an approximation, of course, because it is based upon the assumption that the mean stress is equal to half the sum of the maximum and minimum stresses, which all engineers familiar with the indicator-diagram know to be not quite true. It could, in fact, be true only if the hyperbolic curve were a straight line, whereas the most that can be said is that, when only small arcs are in question the radius of curvature is much greater than the length of the arc. Nevertheless, in most cases, it will be found that the approximate formula (A) will give results which very nearly approach the results obtained from the rational formula (G), the pressure, of course, always being convergent.

A still closer approximation to the rational formula (G) may be made as follows: Up to the practical maximum value of $\frac{R}{r}$ already stated, it is a fact that:

$$\text{Log}_e \frac{R}{r} = \frac{2(R-r)}{R+r} \text{ very nearly.}$$

Substituting this value of the logarithm in the formula (G):

$$\frac{2(R-r)}{R+r} = \frac{pR}{fr}.$$

The reduction of this equation is a rather tedious process, and need not be here stated at length. As a simple equation, it reduces to:

$$\frac{r}{t} + \frac{t}{2r} = \frac{f}{p} - \frac{3}{2},$$

and can only be solved as a quadratic equation. Completing the square and reducing, the simplest way of stating the result when solving for t is to put:

$$\frac{f}{p} - \frac{3}{2} = m.$$

Then $$t = r\{m \pm (m^2-2)^{\frac{1}{2}}\} \quad . \quad . \quad . \quad . \quad . \quad (L)$$

The ambiguity may always be read as minus, provided that the practical maxima and minima are adhered to.

There is no need to deduce approximations to the formula (F), applying to cylinders pressed internally, as it is already simple enough.

Spherical Dams.—It is with some diffidence that the writer approaches this part of the subject. Mining literature appears to be destitute of any formulæ by which one can compare one's results; and, it is equally destitute of any rational rules dealing with cylinders under external pressure. It is true that Prof. Aldis has framed some formulæ for cylindrical and spherical dams, but the discovery that his formula for the cylinder is merely an approximation rather shakes one's confidence in the absolute rationality of his rule for the spherical dam.

Then, just as a cylinder may be imagined as an assemblage of wedge-frustums, so also a sphere may be regarded as a structure built up of frustums of pyramids. Having this difference in remembrance, then, a precisely similar line of reasoning to that employed in the case of the cylinder leads, in the case of the sphere, to the enunciation of the following rule:

$$\text{Log}_e \frac{A}{a} = \frac{pA}{fa}.$$

A is the external surface of the sphere receiving the pressure p; and a is the internal surface subjected to the maximum stress f. If we put it in another way, we have

$$\frac{A}{a} = \frac{f}{p} \text{Log}_e \frac{A}{a}.$$

The same law of maxima obtains in the sphere with regard to the value of $\frac{A}{a}$ as obtains in the cylinder with regard to the value of $\frac{R}{r}$; and the minimum value of $\frac{f}{p}$ with regard to $\frac{A}{a}$ cannot be less than e. But $\frac{A}{a}$ equals $\frac{R^2}{r^2}$; hence

$$\text{Log}_e \frac{R^2}{r^2} = \frac{p}{f} \frac{R^2}{r^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (M)$$

and $\frac{A}{a} = \frac{R^2}{r^2}$ is greater than $e \text{Log}_e \frac{R^2}{r^2}$;

hence the

$$\text{Minimum value of } \frac{f}{p} = e;$$

and the practical minimum is always greater than e.

Example.—A deep pit has approached the old abandoned workings of an equally deep pit, now filled up with water. A cast-iron dam is to be put in a heading which is deemed dangerously near to the old workings. The estimated pressure of the head of water is 800 pounds per square inch, and the safe stress permissible is supposed to be 12,000 pounds per square inch. The dam is to be a spherical one. Find the value of $\frac{R}{r}$.

Answer.—From formula (M):

$$\frac{R^2}{r^2} = \frac{12{,}000}{800} \text{Log}_e \frac{R^2}{r^2} = 15 \text{Log}_e \frac{R^2}{r^2}.$$

Looking in the tables, this condition is fulfilled by some number between 1·07 and 1·08. Now 1·08 is about 14 times greater than its logarithm, whilst 1·07 is nearly 16 times greater than its logarithm. Hence, not to be tedious, 1·075 is about 15 times as great as its logarithm. Then

$$\frac{R^2}{r^2} = 1{\cdot}075,$$

and $\frac{R}{r} = \sqrt{1{\cdot}075} = 1{\cdot}037$ very nearly.

Approximate Formula for Spherical Dams.—This may be obtained, without the use of logarithms, by substituting the approximate value of $\log_e$ in the formula (M), which then becomes:

$$\frac{2(R^2 - r^2)}{R^2 + r^2} = \frac{p}{f}\frac{R^2}{r^2}.$$

Solving this rule to find the value of $\frac{R}{r}$ is a tedious process, and it will suffice to state the final result, namely:

$$m = \sqrt{\frac{f^2}{p^2} - 3\frac{f}{p} + 0{\cdot}25};$$

and

$$R = \sqrt{\frac{f}{p} - 0{\cdot}5 \pm m}.$$

Here, again, in all practical cases, the minus sign of the ambiguity must be taken. If, however, the numerical value of $\frac{f}{p}$ be less than $1\frac{1}{2} + \sqrt{2}$, the numerical value of m will itself be a minus quantity which, being preceded by a minus sign, will become a plus value.

All the formulæ, rational and approximate, as set forth in this appendix, have been independently deduced without recourse to the calculus, in order that the theory of strains in cylindrical and spherical structures may be made comprehensible to all students, whatever be the extent of their mathematical attainments. And if those who are more expert in this direction will examine the formulæ here submitted, and point out any errors which may have crept in, no one will be more pleased or more grateful than the writer. The following is a synopsis of the results.

(1) *Rising Mains.*—The rational formula is:

$$\text{Log}_e \frac{R}{r} = \frac{p}{f}.$$

(2) *Cylindrical Dams and Tubbing.*—The rational formula is:

$$\frac{R}{r} = \frac{f}{p}\text{Log}_e \frac{R}{r}.$$

The minimum value of $\frac{f}{p}$ is e, but practically it is greater than e. The practical maximum of p equals $\frac{1}{4} f$. The practical maximum of $\frac{R}{r}$ equals $\sqrt{2}$. The approximate formula most nearly approaching the rational rule is:

$$t = r\left\{m \pm \sqrt{(m^2 - 2)}\right\};$$

where

$$m = \left\{\frac{f}{p} - \frac{3}{2}\right\}.$$

(3) *Spherical Dams.*—The rational formula is:

$$\text{Log}_e \frac{R^2}{r^2} = \frac{p}{f}\frac{R^2}{r^2}.$$

The same laws of maxima, which apply, in the case of cylinders, with respect to the ratio of the radii, also apply, in the case of spherical structures, with respect to the ratio of the squares of the radii. And generally, for the same values of p and f, the formulæ for spherical dams differ from those for cylindrical dams only in the fact that the squares of the radii replace the first powers of the radii which appear in the rational formulæ of cylinders.

The approximate formula for spherical dams is :

$$\frac{R}{r} = \sqrt{\frac{f}{p} - 0{\cdot}5} \pm m;$$

where

$$m = \sqrt{\frac{f^2}{p^2} - 3\frac{f}{p} + 0{\cdot}25}.$$

The numerical value of m vanishes when $\frac{f}{p}$ equals $1\frac{1}{2} + \sqrt{2}$; and becomes a minus quantity when the value of the ratio $\frac{f}{p}$ is less than $1\frac{1}{2} + \sqrt{2}$.

Mr. T. A. O'Donahue (Wigan) wrote that Mr. Halbaum's complete rational formula was little different from other existing formulæ, except that he left to the engineer the task of assigning values to the factors. Were the engineer in a position to determine correctly the values of the factors, this would be an easy task; but as some of them could not be even approximately estimated, and further data were required to approximate others, no rule, however correct mathematically, was of much practical value which did not give some assistance in determining the unknown factors. Mr. Halbaum objected to the thin-cylinder rule (4) ordinarily employed. It was well known that it was not strictly correct to apply this rule to shaft tubbing, and he had pointed this out in his paper.* The more precise formulæ referred to by Mr. Halbaum, however (A, B, C, and D), afforded results so little different, that there was no inducement to adopt a more complicated formula when the factors could not be accurately determined. The hydrostatic pressure afforded the only basis for the calculation of the stress on tubbing. An approximate estimate of other pressures was impossible, and an allowance could only be made for them in the factor of safety. The necessary allowance for deterioration might, to some extent, be fixed by the prevailing conditions; but it was not exceeding the latitude allowed to an empirical rule to fix an allowance suitable for normal conditions. The same remark applied to the allowance for imperfections in casting. He (Mr. O'Donahue) agreed that the allowances given in the old rules for deterioration and imperfections were inadequate for thin plates, and that moderately correct results were obtained only by allowing an excessively high factor of safety in the

* "The Thickness of Cast-iron Tubbing," by Mr. T. A. O'Donahue, *The Colliery Guardian*, 1905, vol. xc., page 314.

formulæ. With regard to Mr. Halbaum's statement that he (Mr. O'Donahue) had attempted to teach that the thickness need not increase even as fast as the pressure increases,* he might reply that Mr. Halbaum's formula taught the same; otherwise the allowance for deterioration and imperfections would have to increase materially with the depth. The allowance need not be greater; in his (Mr. O'Donahue's) opinion it might be less in a thick plate than in a thin one: in which case the theoretical factor of safety, based on the pressure only and taking the full thickness of the metal, decreased with the depth. It was for this reason he objected to Prof. Bodart's formula, in which there was no special allowance for deterioration and the thickness varied directly as the pressure. He (Mr. O'Donahue) considered that the thin-cylinder rule (4), with an allowance added for deterioration, etc., was suitable for all practical requirements, providing there was a proper disposition of flanges. Thus:

$$t = \frac{prf}{c} + a;$$

where t is the thickness of metal in inches; p, the pressure in pounds per square inch; r, the radius of the shaft in inches; f, the factor of safety; c, the crushing strength of the metal in pounds per square inch; and a, the addition for deterioration, etc. The important questions to decide, and as to which discussion was desirable, were the values to be assigned to the factor of safety and to the allowance for deterioration, etc. He considered that a factor of safety of 6 or 7 would be adequate; and for normal conditions he would give a a value of from 0·4 to 0·75, according to the diameter of the shaft, etc., for the top plates, and decrease the allowance slightly with the depth. Many general rules were adopted, to apply to more varying conditions than obtained with tubbing, and if the members of the Institution would assist in this matter, there was no reason why a more or less trustworthy rule should not be approved.

Mr. C. Pilkington (Clifton) wrote that many of the present formulæ for the thickness of the metal gave widely different results, quite apart from making no mention of flanges and ribs. He understood that it was better in every way to work out the formula, regarding tubbing as a plain cast-iron cylinder, into which three questions would enter:—(1) the theoretical thick-

* "The Thickness of Cast-iron Tubbing," by Mr. T. A. O'Donahue, *The Colliery Guardian*, 1905, vol. xc., page 15.

ness necessary for the diameter and the crushing pressure; (2) the allowance for corrosion; and (3) the allowance for safety. These three items, when added together, gave the thickness of metal; and segments of certain diameters and thicknesses should have flanges and ribs of proportionate strength. The flanges, as Mr. Halbam stated, were used for fixing purposes, but this did not apply to the ribs, which had always been cast on tubbing. The present British and German tubbing obtained, he believed, increased strength from the flanges and ribs: therefore, although they might not enter into the calculation (it was safer to omit them), they must be taken into consideration by the practical engineer. It was well to remember that there might be shaft-strains other than the horizontal pressure due to depth. He thought that colliery-proprietors would willingly give their experiences of tubbing, and would afford facilities for its examination; but as the proof of durability was forthcoming about 50 years later, the figures up to now were often unreliable, and usually none were available.

Mr. T. C. Futers (Newcastle-upon-Tyne) wrote that it was without doubt a singular thing, that so many attempts had been made to produce a satisfactory formula for cast-iron tubbing, whilst little or no difficulty should have been experienced in this direction in regard to walling; and he could only put it down to the fact that most brick-walling was put in without referring to a calculation as to what was the most economical thickness. As a rule, however, brick-lining was not adopted if there was a quantity of water to be kept back, but merely to protect the shaft when passing through bad ground, and to give it a finished appearance; and the engineer in most cases decided the thickness of the wall "by his eye," so to speak (and it might here be remarked that a good "engineering eye" was worth much more than any formulæ). In all probability, the thickness of the tubbing put in by the "grand old engineers" in the past was decided by the eye, rather than by referring the matter to a mathematical investigation; and this much at least might be said for Mr. Greenwell's formula, that it had stood the test of time, and the only objection that could be brought against the tubbing of the "grand old engineers" was not that it was not strong enough, but that they had underestimated the length of

time that the tubbing was required to last. He (Mr. Futers) had not heard of a single instance where tubbing had failed owing to a want of sufficient strength to resist the pressure of the hydrostatic head of water. Accidents had happened by a section of tubbing being burst or blown out, owing perhaps to a faulty casting or to the kinetic energy stored in a moving column of water, air, or gas; but these were extraordinary incidents, and should be dealt with as such. It was useless to attempt to devise formulæ for the thickness of tubbing necessary to withstand extraordinary and unexpected pressures. The most difficult point, however, was with regard to the material itself. Cast-iron was the most unreliable metal—except for masses subject mainly to compressive strains—that the engineer had to use, and practically nothing more was known about its properties at the present time than in the days of our forefathers. Certainly its use was becoming more and more restricted every day, and steel, in the shape either of rolled sections or of castings, was taking its place. Why then should cast-iron still be adhered to for shaft tubbing? Probably the worst feature in connection with cast-iron tubbing was corrosion, which, in his opinion, was purely a chemical action; and the difficulty would be to devise a formula for t_1 that would meet all cases of corrosion, as the destruction due to this cause might be much more rapid in some cases than in others. He would certainly advise the removal of this quantity of t_1 altogether, and so arrange matters that the tubbing would not corrode. This could easily be done; hence this extra thickness was not required, and the formula was simplified. He (Mr. Futers) was rather surprised that Mr. Hodges, in the tubbing used at Methley Junction colliery, should first use Dr. Angus Smith's composition to guard against corrosion, and then put an extra thickness on the tubbing to allow for corrosion. There was surely a lack of faith in the anti-corrosive composition. In his (Mr. Futers's) opinion, a compound bitumen-asphalt was better than Dr. Angus Smith's composition.

The question, as to whether tubbing should be treated as a thin collapsible tube, or as an arch, and whether the stiffening ribs should be taken into consideration or left out, required careful consideration. He was inclined to think that a section of the tubbing should be treated as a ribbed arch. Too little was known, both in theory and practice, with regard to long columns

and thin tubes, to render the application of these formulæ absolutely safe and reliable in relation to tubbing. Let them consider, for instance, a large tube of thin material—a tin case, for example—how easily it was dented, and how it might be partly dented, and on the removal of the pressure would return to its normal condition. Was the metal in tension or compression? He (Mr. Futers) was not satisfied with Prof. W. Galloway's formula, and he had modified it* to meet current practice, with the concurrence of Prof. Galloway. He had, consequently, no hesitation in recommending it as a practical reliable formula to determine the thickness of tubbing to resist the pressure-head of water. This pressure was under discussion when the writer made the statements, quoted by Mr. Halbaum,† *re* the dimensions of tubbing adopted on the Continent. He (Mr. Futers) then stated that it was absurd to put in cast-iron tubbing, for (he believed) a 12-feet diameter shaft, 5 to 7 inches thick; and, further, he could not agree with Mr. Halbaum that formulæ applicable to a retaining-wall could be applied to shaft-tubbing.

Prof. W. Galloway (Cardiff) wrote that Mr. Halbaum's chief contentions in his paper were as follows:—(1) That sufficient consideration had not been given to the question of corrosion by his predecessors; and (2) that the formulæ, hitherto employed in calculating the thickness of tubbing, were not sufficiently accurate.

In regard to the first contention, external corrosion by stagnant water behind the tubbing was impossible, when the space between the tubbing and the ground was filled with concrete or cement, however acid that water might be; and internal corrosion by acid vapours in the shaft could be prevented by means of a thin lining of brick or otherwise, where necessary.

In regard to the second contention, the mathematically exact formula, due to Prof. Lamé, was as follows:—

$$e = \frac{D}{2}\left(\sqrt{\frac{R - p_o}{R - p_o - 2\omega H}} - 1\right) \quad . \quad . \quad . \quad (A)$$

in which: H is the piezometric height of the water in metres; D, the internal diameter of the shaft in metres; e, the thickness

* *Mechanical Engineering of Collieries*, by T. C. Futers, 1905, pages 67 and 68.

† "The Thickness of Cast-iron Tubbing," by Mr. T. C. Futers, *The Colliery Guardian*, 1905, vol. xc., page 314.

of the lining, of whatever kind, in metres; R, the resistance in kilogrammes per square metre which the lining can support; ω, the weight in kilogrammes of a cubic metre of water; and p_o the atmospheric pressure in kilogrammes per square centimetre.

The formula* reproduced by Prof. H. Louis and himself (Prof. W. Galloway) was:—

$$T = \frac{WHD}{2(R - WH)} \quad . \quad . \quad . \quad . \quad . \quad (B)$$

in which, W is the weight of a cubic inch of water in pounds; H, the depth below the piezometric level, in inches; D, the diameter of the shaft in inches; R, the pressure in pounds per square inch required to crush cast-iron, divided by an empirical factor of safety; and T, the thickness in inches. An error was made in substituting + for − in the denominator, but as the quantity expressed by WH was very small, compared with the value of R when referred to cast-iron, it did not appreciably affect the result; and, as would be shown presently, WH could be eliminated from the denominator without sensible error.

In the formula of which Mr. Halbaum appeared to claim to be the inventor, the essential part, namely: $pr \div (f - 1{\cdot}6p)$ was identical with the one given above, except in regard to the co-efficient 1·6, since $p = WH$, $r = \frac{1}{2}D$, $f = R$, and $1{\cdot}6p = 1{\cdot}6WH$. He (Prof. Galloway) could not trace the origin of the co-efficient 1·6, but as WH was a small quantity, and according to M. Haton de la Goupillière, could be neglected,† so also could $1{\cdot}6p$. To his formula, Mr. Halbaum had added l/n, the utility of which was doubtful in the face of his preceding remarks.

The formula recommended by M. Haton de la Goupillière,‡ one of the first mathematicians in France, was

$$e = \frac{\omega HD}{2R} \quad . \quad . \quad . \quad . \quad . \quad . \quad (C)$$

which, with the symbols employed by the writer (Prof. W. Galloway), becomes:

$$T = \frac{WHD}{2R} . \quad . \quad . \quad . \quad . \quad . \quad (D)$$

In calculating the thickness of cast-iron tubbing required for a shaft, 4 metres in diameter, 100 metres deep below the piezo-

* *Exploitation des Mines*, first edition, 1884, vol. i., page 281. The symbols used by M. Haton de la Goupillière in the first edition of his work and reproduced in the third edition, vol. ii., page 837, were: $e = \varpi HD + 2(R - \varpi H)$.

† *Ibid.*, third edition, 1905, vol. i., page 851. ‡ *Op. cit.*

metric level of the water, and assuming that R equalled 5,000,000 kilogrammes per square metre, or about one-tenth of the pressure required to crush cast-iron, M. Haton de la Goupillière arrived at the following figures: (1) By Prof. Lamé's exact formula, 41 millimetres; (2) by formula *c*, 40 millimetres; and he remarked that the latter value was sufficiently approximate to the exact figure.*

In calculating the thickness of tubbing required at the bottom of a shaft, 450 feet deep and 20 feet in diameter, by means of his (Prof. Galloway's) formula, Mr. Halbaum arrived at the thickness 0·9 inch, which he erroneously attributed to some imperfection in the formula. If he had taken a factor of safety of one-twelfth, he would have obtained 3·57 inches: in fact practically the same thickness as his so-called "complete rational formula" would give him, if divested of its adventitious element l/n. Taking the value of R as 6,720 pounds in the formula, it follows that $T = [(0{\cdot}036 \times 5{,}400 \times 240) \div 2\,(6{,}720 - 0{\cdot}036 \times 5{,}400)]$ $= 3{\cdot}57$ inches, and by eliminating $-0{\cdot}036 \times 5{,}400$, it follows that $T = 3{\cdot}47$ inches, or only 0·10 inch less.

The formula $T = \frac{WHD}{2R}$ is, therefore, obviously sufficient for all practical purposes on the assumption that the person employing it possesses ordinary intelligence; for he would then know (1) that at its upper end the tubbing must be thick enough to admit of its being cast in moulds and handled without the risk of being broken; and (2) that the factor of safety he could afford to employ depends upon several considerations, cost amongst others, over which he would naturally desire to exercise some control.

Prof. Henry Louis wrote that he was much disappointed in Mr. Halbaum's paper, as his complete rational formula (8) appeared to him to be rather less rational than those of his predecessors. It consisted of two terms, the first of which was to represent a thickness of metal to allow for corrosion, and the second a thickness to resist crushing. The former postulated that corrosion was always inevitable, and was further based upon an assumption, in favour of which no evidence at all was adduced, namely, that if a given thickness of metal were dissolved off tubbing in one year, l times as much would be dissolved in l years. There was really nothing definite known as to the

* *Exploitation des Mines*, first edition, 1884, vol. i., page 281. The symbols used by M. Haton de la Goupillière in the first edition of his work and reproduced in the third edition, vol. ii., page 837, were: $e = \varpi HD + 2\,(R - \varpi H)$.

laws that regulated the rate of corrosion, but it was tolerably certain that no such simple arithmetical ratio as this existed; corrosion in the first year was probably more rapid than in the second, and might conceivably in a certain number of years cease altogether; this was by no means sure, and almost the only thing that could be said to be sure was that Mr. Halbaum's simple-proportion theory was wrong. Furthermore, it seemed to have escaped Mr. Halbaum's attention that this "corrosion term" was really not necessary; all that was needed was to select a factor of safety sufficiently great, so that even after a given quantity of metal had been dissolved away, the factor of safety would not be reduced below some desired safe figure. It would be shown subsequently that this method had been adopted by quite reliable authorities. He (Prof. Louis) agreed with Mr. Halbaum's views on the subject of the factor of safety (Note on the value of f), but he thought that he might well have carried them further, to the conclusion now indicated. Mr. Halbaum's second term, so far from being a rational formula, appeared to be rather an empirical approximation to the average of the rational formulæ of other authorities, some of which were, however, specially applicable only to internal pressures.

There was only one way of obtaining a true rational formula for such a problem as this, and that was by a rigorous mathematical analysis of the whole subject, based on first principles, and this was precisely the course that Mr. Halbaum had not adopted. He had, indeed, quietly disregarded the main difficulty of the whole problem, inasmuch as he had treated a ring of tubbing as a plain cylinder, which was precisely what it was not. The ordinary cylinder-formulæ applied to continuous cylinders, not to segments pressed or joined together. Probably mathematical analysis would demand that each segment should be treated as an arch resting against abutments constituted by the rest of the ring, with the peculiarity that the thrusts on such an arch took place along radial lines, and not, as usual, along parallel lines; it had also been suggested that possibly tubbing should be treated as though each pair of adjoining plates formed a hinged arch, although this treatment seemed to present more difficulties than the one first suggested. It was quite unnecessary for Mr. Halbaum to trouble about the simple case of the plain cylinder, disregarding both the horizontal and vertical ribs and flanges, because that com-

paratively simple problem, which was all that he had attacked, had been solved long ago. He (Prof. Louis) had pointed out elsewhere that a correct formula had been used for the "ice-tubbing" formed in the freezing process of shaft-sinking, by Mr. H. Pœtsch, and following him, by Prof. Schmidt and others: this being a strictly rational formula, namely:—

$$t_x = r\left(\sqrt{\frac{f}{f-2p}} - 1\right),$$

where $$p = wsh \tan^2\left(45° - \frac{\phi}{2}\right),$$

using the same notation as that employed by Mr. Halbaum.* It might be added that he (Prof. Louis) had pointed out that this was the expression that had been got out independently by other workers, the first part being the formula of Prof. W. S. Aldis† (which was practically the same as that of Prof. Lamé) for the thickness of cylinders to resist external pressure, and the second the formula for the pressure of earth against a vertical surface; obviously the latter formula applied equally well to the special case of a pressure of water, in which case s equalled 1, and ϕ equalled 0. The above formula could be used satisfactorily for shaft-linings of brickwork, concrete, etc., and should be applicable also to a plain cylinder of cast-iron.

In practice, however, a simpler empirical formula, which came to practically the same thing, was used in the only cases in which actual cylinders of cast-iron were employed, namely, in the Kind-Chaudron and similar processes. Thus Mr. Chaudron had used for many years the following formulæ:—

$$E = 0{\cdot}02m + \frac{RP}{500}, \text{ for depths less than 50 metres} \quad . \quad . \quad (a)$$

$$E = \frac{1m}{H} + \frac{RP}{500}, \text{ for depths greater than 50 metres} \quad . \quad (b)$$

where E is the thickness of tubbing in metres; H, the depth below water-level in metres; R, the internal radius of the tubbing in metres; and P, the external pressure in kilogrammes per square centimetre. The co-efficient 500 represented the greatest admissible strain on cast-iron; as its resistance to crushing was usually taken at about 7,500 kilogrammes per square centimetre, the factor of safety was taken at one-fifteenth. Obviously these equations might also be (more conveniently) written:—

* This is merely another form of Prof. Rankine's formula, quoted by Mr. Halbaum.

† *Trans. N. E. Inst.*, 1883, vol. xxxii., page 201.

$$E = 0{\cdot}02m + \frac{RH}{5{,}000}; \text{ and} \quad (a)$$

$$E = \frac{1m}{H} + \frac{RH}{5{,}000} \quad (b)$$

Reduced to British measurements (t and r in inches and h in feet), these formulæ were respectively:—

$$t = 0{\cdot}08 \text{ inch} + \frac{rh}{16{,}400}, \text{ when } h \text{ is less than 164 feet} \quad (a)$$

$$t = \frac{130 \text{ inches}}{h} + \frac{rh}{16{,}400}, \text{ when } h \text{ is greater than 164 feet} \quad (b)$$

When it was remembered that the thicknesses of all the cylinders used in all the Kind-Chaudron sinkings (some 80 in number) had been calculated by these formulæ, it seemed pretty safe to say that they had proved to be reliable in practice. Mr. J. Riemer held that whilst these were the proper formulæ for comparatively shallow shafts, they gave too high results for deep shafts. He held that for shafts 300 or 400 metres in depth the first term might be neglected; also that a lower factor of safety (about one-tenth) might be adopted with the reliable castings now available, and that for shafts 400 metres deep or more it was safe to adopt the expression $E = RP/800$, or

$$E = \frac{RH}{8{,}000}\left(t = \frac{rh}{26{,}300}\right).$$

It would be seen, therefore, that the best modern Continental practice favoured the method of omitting the corrosion factor, and using a variable factor of safety. Mr. Chaudron's formula was 50 years old, and had stood the test of practical experience, so that the problem might fairly be said to be sufficiently solved for plain cylinders exposed (like Kind-Chaudron cylinders) to pressure of water alone, and this was all that Mr. Halbaum had now attempted. It must be emphasized that he had not even attacked the problem of ordinary tubbing. They were as far off a solution as ever where tubbing proper, composed of segments, was concerned, and a mere statement of the real difficulties of the case, which Mr. Halbaum had not attempted to confront, showed what still remained to be done before a rational formula could be set up. Should the thickness be calculated for strength or for stiffness? Was the arch formula or any modification of it the proper formula to use, or should the hinged-arch formula be employed? What part was played by the vertical ribs and what by the horizontal ribs? If these questions could be successfully answered, the nature of the pressure

to be resisted still remained to be considered; it was easy to calculate the pressure due to a head of water, to quicksand, or to soft ground, alone, but that due to their joint effect was still obscure. Furthermore, could anyone calculate the pressure produced by swelling ground? It was easy to determine the resistance to crushing of any particular cast-iron, but when this was known, it still remained to fix on a suitable factor of safety, having regard to the fact that this might be lowered in time by corrosion, and possibly by molecular changes and other more obscure causes. After all was said and done, the factor of safety—which was the dominant figure in every one of these formulæ—would always have to be fixed empirically, and since this was the case, attempts to get at a rational formula had mainly an academic interest. Until a thoroughly rational theory could be set up, it was better frankly to adopt empirical data for thickness, based on experience, and which they knew gave an ample margin of safety.

Mr. J. J. Prest (Horden collieries) said that, after careful study of Mr. Halbaum's paper, he agreed with the deductions. The formula (8) appeared to cover all the elements to be considered in ascertaining the thickness of metal required in cast-iron tubbing. The difficulty, of course, would be to obtain with any degree of accuracy the elements l/n of the formula, and in the end, no doubt, this would resolve itself into the addition of one-third, one-half, two-thirds, or may be 1 inch, to the thickness of cast-iron calculated to be required to overcome the statical pressure of water, pretty much as was provided by Mr. G. C. Greenwell's formula. He quite agreed with Mr. Halbaum that the whole of the work incidental to the lining of the tubbing in the middle pit at Murton colliery was designed and executed in an admirable manner; but it did not by any means follow that feeders of water encountered in the sinking of shafts should be tubbed off in like manner. Having in view, however, the larger diameter of modern shafts, and the experience of the past 50 years in sinking through more difficult ground, and in the corrosive nature of feeders of water frequently encountered, the time had arrived when it would be desirable to ascertain whether the usual British method of tubbing back feeders of water in sinking pits was really the safest and most expeditious method of overcoming the difficulty. He was personally of the opinion that the tubbing segments might conveniently be 4 feet in depth,

and, in many cases, that internal flanges with metallic joints would be simpler; also that these segments should, after being properly tested, be coated with Dr. Angus Smith's composition, and the whole of the tubbing backed up solid with good cement-concrete. There was no doubt whatever that tubbing in shafts sunk 60 or 70 years ago, and more particularly in furnace upcast-shafts, was put in much too thin to provide for the decomposition set up by the sulphurous fumes from the furnace on the inside, and the corrosive action of deleterious waters tubbed back in the strata on the outside; and it was probable that many of these shafts would have to be re-lined. The variation in the thickness of the segments of tubbing at the Methley Junction colliery in Yorkshire might or might not have been due to corrosion. The most extraordinary feature in connection therewith was the great variation in the thickness of metal in each segment of tubbing, which appeared to suggest that some of the test-holes had been bored through the strengthening ribs at the back of the tubbing: otherwise there was no reason why the depreciation in thickness should not have been uniform over the whole of the segments. Mr. Halbaum would not mind his saying that it was not good practice to use iron wedges in the joints of any kind of tubbing, and that it was usual for the thickness of metal to be delineated in raised figures on the inside of each segment: also that if the mixture of iron required was specified, the castings themselves inspected, and a certain percentage tested to destruction, there was no necessity to make any mathematical allowance for imperfections in casting.

Dr. J. Morrow (Armstrong College) wrote that, as pointed out in the paper, the strength of hollow cylinders must be considered quite apart from their resistance to collapse. The question of collapse, however, could not be put on one side. A simple cylinder, without ribs or flanges, subjected to a uniform external pressure, p, retained its shape until p reached a certain critical value. When this critical pressure was reached, the circular form was not necessarily stable; it became possible, in fact, for the cylinder to assume some shape other than circular. It was this possibility that constituted the danger. The critical pressure might be shown, for a long cylinder, to be proportional to the third power of the ratio of the thickness to the diameter. Flanges and ribs reduced the effective length of the cylinder, and thus raised the critical pressure; but it might

easily happen, in the case of deep shafts, that these stiffeners would have to be placed very close together, and it would then be more convenient to increase the thickness of the shell (over and above that given by strength-formulæ), and so decrease the number of stiffening rings required. With regard to the strength of the segments of the tubbing to resist the crushing forces which acted on them, it was necessary first to define the way in which these forces acted. If the tubbing was assumed to be cylindrical, and the pressure on its outside was uniformly distributed, and was everywhere normal to the surface, the stress in the material was compressive. Its greatest value was found to occur as a hoop or circumferential stress close to the inner surface of the cylinder. This stress might be calculated by equation (A) of Mr. Halbaum, which was the result of Prof. Lamé's theory.

If $2p$ could be neglected in comparison with f, equation (A) was reduced to equation (4), d being then the mean diameter. Mr. Halbaum seemed to have obtained equation (6) by virtue of equation (4), and then to have used it for purposes to which equation (4) was not applicable. This had caused a slight error in (D), as might be seen by comparing columns (A) and (D) in Table I. The formulæ (A) and (D) were, when correctly stated, identical. Formula (C) was based on a different assumption, but agreed very closely with equation (A). As given in Mr. Halbaum's paper, however, both of these equations, (B) and (C), were vitiated by having been subjected to equation (6).

When, on the other hand, it was supposed that the pressure on the outside of the cylinder was not purely radial, or was not everywhere of the same intensity, these formulæ could not be used. In this case, the problem must be dealt with by methods similar to those employed in the consideration of metal or masonry arches. When the pressure was uniform and purely normal, and the surfaces were cylindrical, the employment of an arch formula would be out of the question. The allowance made by the author for deterioration of the material seemed large; but if the paper led to a systematic collection of data on the subject of corrosion, it would have done valuable service.

The geometrical construction given in the appendix was laborious; and that ordinarily used for the factor $\frac{1 - \sin \phi}{1 + \sin \phi}$ was very much simpler.

Mr. H. W. G. Halbaum, replying to the discussion, thought that a more careful perusal of his paper would remove some of the misapprehensions that appeared to obtain. Certainly a reference to his paper would quickly dispose of some of the surprising statements made by Prof. Louis. However, he (Mr. Halbaum) would point out to Messrs. O'Donahue and Futers that they had in *The Colliery Guardian* discussed the case of shafts 18 feet in diameter and pressures up to 1,500 feet of water. In such cases, the error of the thin-cylinder formula was not small, nor was tubbing 7 inches thick necessarily absurd. The real absurdity lay in using formulæ admitted to be erroneous, when a better class of rule lay ready to hand. Factors of safety, having a numerical value of 15 or other ridiculous proportions, might be reliable, but they did not belong to engineering, which combined safety with economy; any amateur could combine it with waste.

He (Mr. Halbaum) was sorry if he had not done justice to Prof. Galloway's formula; but he would like Prof. Galloway to say plainly what his formula really was. Was it that quoted by Prof. Louis, or not?* Or was it the amended rule by Mr. Futers? Or was it the rule which one of H.M. inspectors of mines recently declared† "should, in future, be dispensed with as being altogether misleading?" Prof. Galloway, however, now desired to amend it still further: (1) he gave a formula, and marked it (A), but this was Prof. Lamé's rule; (2) then he (and Prof. Louis) reproduced a formula from the French, and marked it (B) in his printed remarks. That, however, was not Prof. Galloway's rule, for it was credited to Mr. J. J. Atkinson in the *Transactions* of The North of England Institute of Mining and Mechanical Engineers long before Profs. Louis and Galloway reproduced it from the French. Prof. Galloway's formula, marked C, was public property half a century since. Consequently, the only original item of the entire reproduction from the French was that part where the error was made of substituting + for − in the denominator. Prof. Galloway now desired to eliminate that error, forgetting that the error was the only thing that differentiated his formula from Mr. Atkinson's. It might be asked, in the interests of mining education, why Prof. Galloway had

* *Practical Coal-mining*, by Leading Experts in Mining and Engineering, under the Editorship of Prof. W. S. Boulton, 1907, divisional volume i., page 138.

† *Trans. Inst. M. E.*, vol. xxxiii., page 121.

allowed his formula to face the public for so many years before he chose to acknowledge the error in the denominator.

With respect to the allowance l/n for corrosion and the general character of formula (8), Prof. Louis stated only what had already been stated in the paper, and he had certainly not discovered anything that was intended to be concealed. Against the approximately rational formula (8), however, he set what he was pleased to call a "strictly rational formula," the body of which was due to Prof. Aldis, and the application of which to the tubbing case (which was the only case for which formula (8) was stated) would give the same numerical results as formula (8) gave: a statement clearly proved by Table I. in the paper. Appendix III. proved that Prof. Aldis' formula was not strictly rational, as Prof. Louis imagined, but merely an approximation to the rational rule, and not even the closest that could be obtained. Coming to his supplementary formula for the value of p, he (Mr. Halbaum) had seen it previously in another of Prof. Louis's papers,* and had at once set it down as an obvious misprint. It now appeared, however, that Prof. Louis was prepared to adhere to it as a "strictly rational formula" for p, and he set it against the rule stated for p in the paper. The respective merits of the formulæ were easily decided by Prof. Louis's own criterion. He (Mr. Halbaum) had adopted Prof. W. J. M. Rankine's rule for the pressure of earth against a vertical surface, which was:

$$p = swh \frac{1-\sin\phi}{1+\sin\phi},$$

adhering to the notation employed in the paper. Prof. Louis apparently contemned this authority, and stated that:

$$p = \frac{swh}{2} \tan^2\left(45° - \frac{\phi}{2}\right).$$

However, the involved trigonometrical quantity employed by Prof. Louis had the same value as that employed by Prof. Rankine, whatever the actual value of the angle ϕ; and:

$$\tan^2\left(45° - \frac{\phi}{2}\right) = \frac{1-\sin\phi}{1+\sin\phi}.$$

It was a most curious thing in this discussion that Prof. Louis should set up a standard of symmetry as a test of the formulæ. He stated of his formula for p that "obviously [it]

* "Shaft Sinking," by Prof. H. Louis, *Practical Coal-mining*, by Leading Experts in Mining and Engineering, under the Editorship of Prof. W. S. Boulton, 1907, divisional volume i., page 138.

applied equally well to the special case of a pressure of water, in which case S equalled 1 and ϕ equalled 0." But under these conditions, by Prof. Louis's strictly rational formula:

$$p=\frac{wh}{2},$$

and this was obviously false. But by Prof. Rankine's formula, applied under similar circumstances:

$$p=wh,$$

and this was obviously true. It would have been correct if he had stated that the total pressure on the whole height of tubbing per lineal inch of the outer circumference was:

$$p=\frac{wh^2}{2};$$

but then, on the other hand, that result would agree with Prof. Rankine's formula again, and the standard of symmetry, to which Prof. Louis had appealed, would again confirm the formula for p stated in the paper, which was precisely what Prof. Louis desired it not to do.

The formulæ used by Mr. Chaudron were, as Prof. Louis ought to be aware, nothing more nor less than "thin"-cylinder formulæ. The only difference between them and those of Messrs. André, Greenwell and Hollingworth was the difference of the arbitrary numerical constants employed. Mr. Chaudron's rule was simply Mr. Greenwell's tubbing formula with a different factor of safety and an increased corrosion-term, just as Prof. Galloway's formula (C), recommended by "one of the first mathematicians in France," was absolutely the same old "thin"-cylinder formula which every pocket-book of engineering formulæ published during the last sixty years affirmed to be:

$$pd=2ft.$$

The work of the first mathematician of France evidently consisted in approving the substitution of WH for p, and of R for f. Surely Prof. Louis and Prof. Galloway should be able to recognize the old familiar rule-of-thumb formula as it came along, at different times and in different garbs; or how would they recognize the true formula when it appeared?

It was pleasing to learn that so high an authority as Mr. Prest agreed with his (Mr. Halbaum's) views, and it was certainly high time that founders should be able to supply the reliable metal which Mr. Prest referred to in his concluding remark.

Dr. Morrow seemed to have too high an opinion of formula (A), and might be referred to Appendix III. In fact, both Dr. Morrow and Prof. Louis ought to see from Table I. that even the approximate practical formulæ (7) was, within the limits of the tubbing case, a slightly safer and a much more convenient rule than the Aldis formula. It might be freely admitted that equation (6) was only an approximation when applied as in the paper, but within the limits of the tubbing case, the error was not worth noting. The true formula, however, was correctly deduced in the appendix, and that by a mode of reasoning which illuminated the principles in the sight of the practical man, instead of obscuring them by a system of mathematics that few men could follow. Dr. Morrow was also mistaken in thinking that the author had made a large allowance for deterioration. On the contrary, the author had striven to expose the folly of making any arbitrary allowance at all, " large " or otherwise.

The PRESIDENT (Mr. M. Deacon) moved a vote of thanks to Mr. Halbaum for his paper, which had elicited so lengthy a discussion.

Mr. M. WALTON BROWN seconded the resolution, which was cordially approved.

Mr. J. GERRARD (H.M. Inspector of Mines) moved a vote of thanks to the President and Council of the Geological Society, and to the President and Council of the Royal Astronomical Society, for their kindness in granting the use of their rooms; and to the owners of works to be visited during the course of the meeting.

The Rev. G. M. CAPELL seconded the motion, which was very cordially approved.

Mr. W. G. PHILLIPS moved a cordial vote of thanks to the President (Mr. Maurice Deacon), to Mr. J. C. Cadman (Past-president), and Mr. C. C. Leach, for their services in the chair, during the course of the meeting.

Mr. HENRY HALL (H.M. Inspector of Mines) seconded the motion, which was cordially agreed to.

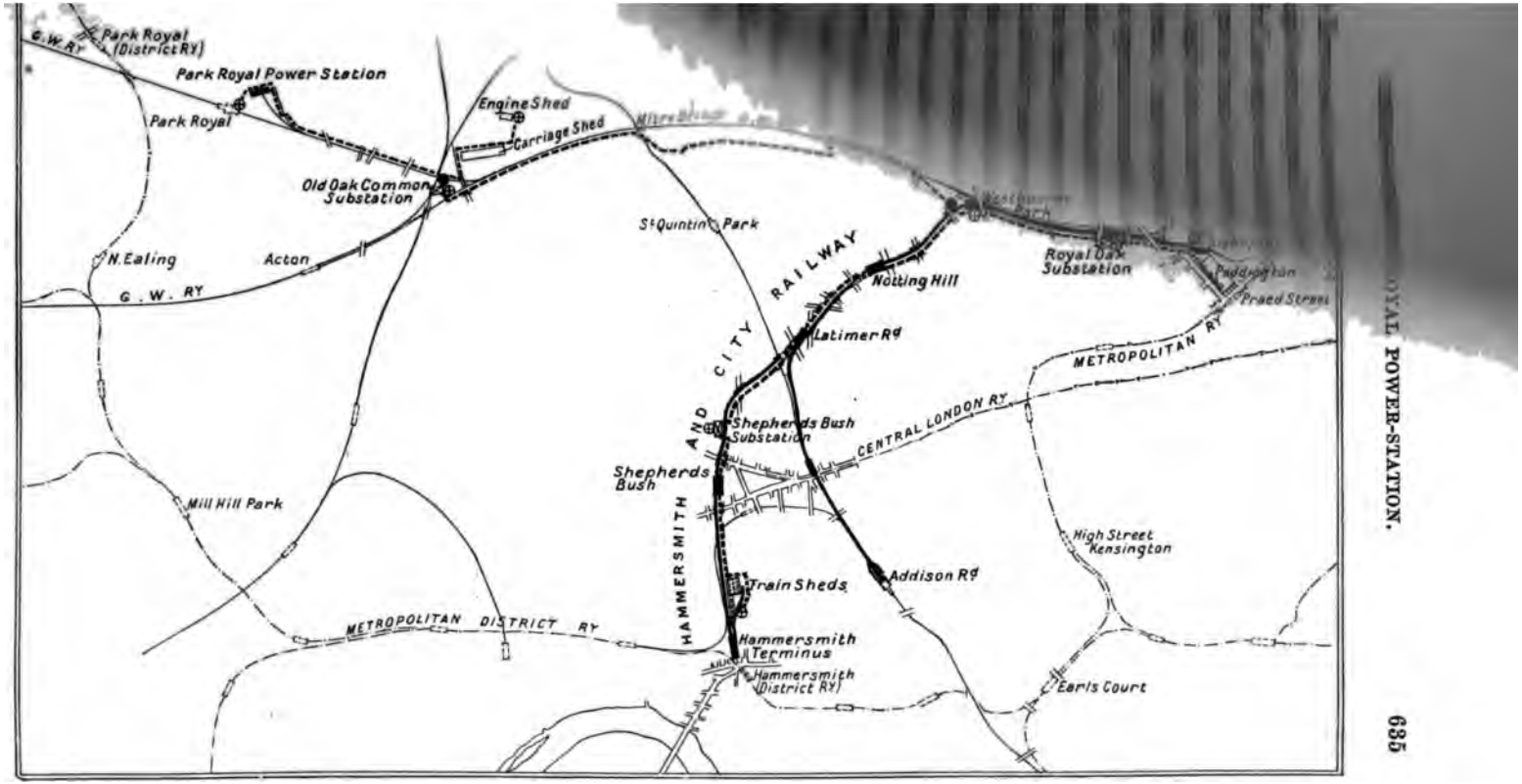

FIG. 5.—PLAN OF HAMMERSMITH AND CITY RAILWAY.

Generating Units.—The main engine-room is built in three bays. Four three-phase generators of 750 kilowatts and engines are placed in line in each outer bay (fig. 6, plate xxv.), making altogether a total capacity of 6,000 kilowatts. The three-phase generators, built by the Electric Construction Company, are of the ordinary rotating field-magnet type, star-connected, but the centre-point is not permanently earthed. They have an overload capacity of 25 per cent. for one hour. The armatures can be slid sideways for inspection or repair. Each generator is direct-coupled to a Belliss & Morcom triple-expansion side-by-side engine running at 250 revolutions per minute. The governor of each engine is controlled by an electric motor from the switchboard gallery, for adjusting the load between sets running in parallel. An electrically controlled emergency-switch is also fitted to each engine, so that under emergency steam could be entirely cut off by the switchboard hand.

Auxiliary Plant.—The excitation-current for the main three-phase generators is obtained from two auxiliary sets and two batteries. One of these exciters is steam-driven and the other is motor-driven. The exciter-generators are similar machines, each of 150 kilowatts output at 220 volts. The auxiliary Belliss & Morcom compound engine, with two cranks, is run at 428 revolutions per minute. The motor driving the second exciter-set is a three-phase induction-motor designed for the full high-tension pressure of 6,500 volts. The batteries, forming a stand-bye for the excitation-supply, are worked in parallel with the exciter-generators, with motor-driven boosters for charging them from the omnibus-bars. Each exciter-generator, with its battery, can be worked by itself, and used for exciting any or all of the main generators when required. Two auxiliary three-phase generators of 150 kilowatts output, one steam-driven and the other motor-driven, generate three-phase current at 650 volts. The steam-engine is a duplicate of that driving the exciter-set described above, and the motor driving the three-phase auxiliary generator is a direct-current motor, taking its supply from one of the exciter switchboards.

The auxiliary three-phase supply at 650 volts is used principally for driving the various motors throughout the generating station, such as the circulating pumps for the condensers, the

automatic stokers on the boilers, the coal-conveyors, etc. A three-phase switchboard for the auxiliary supply is placed on the switchboard-gallery between the two main high-tension switchboards. Two sets of step-down transformers are provided, by which all the auxiliary three-phase plant can be driven when necessary from the main high-tension supply without running any of the auxiliary sets. The motor-driven three-phase generator can be used when required for charging feeders, or it can be run backwards, taking current through the transformers from the high-tension supply or direct from the auxiliary supply, and delivering direct current to the exciter switchboard.

Switchboards.—Two main high-tension three-phase switchboards are placed at the western end of each main engine-room bay. The two boards can be worked independently of each other, or can have their omnibus-bars connected for working in parallel. Each switchboard has a duplicate set of main omnibus-bars and high-tension synchronizing omnibus-bars, used for testing and charging the feeders as well as for synchronizing the generators. Any generator or feeder can be connected to either set of main omnibus-bars. The circuit from each main generator and each feeder is branched and connected to two oil-break automatic switches, each directly connected to one set of the main omnibus-bars. By this arrangement the two automatic switches are used as selector-switches as well, and are also a stand-bye to each other. The machines can be changed from one set of omnibus-bars to the other, through the machine's own switches or through a separate bar-coupling switch. In order to avoid any mistake in synchronizing with the wrong set of omnibus-bars when switching in a generator, a system of mechanical interlocks is fitted at the back of the control-panels.

The high-tension part of the switchboard consists of a steel framework filled in with stone slabs. Each circuit runs from the bottom to the top of the switchboard, and is separated from the others by vertical stone partitions. The switches, transformers, etc., of each circuit are further separated from each other by four horizontal partitions, dividing the whole structure into a set of fireproof cells. Iron doors are fitted to the back of the cells, giving access for inspection and cleaning. The control switchboard is placed on a gallery, and slightly in front of the

Generating Units.—The main engine-room ... d by
bays. Four three-phase generators of 750 k... uments
are placed in line in each outer bay (fig. ... formers,
altogether a total capacity of 6,000 k...
generators, built by the Electric ... placed the
of the ordinary rotating field-m... , and also a
the centre-point is not perm... ne switchboard
overload capacity of 25 p... the engine. At
tures can be slid sidew... e auxiliary three-
generator is direct-co... placed on the same
sion side-by-side e... nels. This auxiliary
The governor of ... of omnibus-bars, and is con-
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Pipe-work.—The main steam-pipes between the boilers and the generating plant are arranged on the duplicate system in the boiler-house and on the ring system in the engine-room. Each boiler is connected to two lines of steam-pipes carried down the sides of the boiler-house and connected across the end of the boiler-house above the pump-room. The ring of pipes in the engine-room is connected to the double line of pipes in the boiler-house through the necessary valves, and is divided into sections by valves between the branch-pipes to the several engines. The whole of the steam-pipes are made from solid-drawn steel tubes.

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face condensers with Edwards air-pumps and circulating pumps, the main engines being connected in pairs to the condensers. A small force-pump is also driven by each air-pump engine for raising the condensed water to the filtering plant. The circulating pumps are of the centrifugal type, each driven by a three-phase motor of 65 horsepower worked from the auxiliary supply of 650 volts. The circulating water is brought by four pipes, run in the basement under the centre bay, to the pump suction-pipes, and, after passing through the condensers, rises vertically to a gallery over the centre bay, 30 feet above the floor level (fig. 8). The water passes back by two pipes along the gallery and out at the western end of the engine-room to a set of four Klein cooling-towers, among which it is distributed by pipes and troughs. The water is collected in large concrete tanks below the towers, from which it is drawn again by the circulating pump suction-pipes.

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Boiler-house Plant.—The boiler-house contains ten Babcock & Wilcox water-tube boilers arranged in two rows of five. Each boiler is fitted with a superheater, and has sufficient heating surface to render the use of economizers unnecessary.

The following notes record some of the features of interest seen by visitors to works, etc., which were, by kind permission of the owners, open for inspection during the course of the meeting on June 13th, 14th and 15th, 1907:—

PARK ROYAL POWER-STATION OF THE GREAT WESTERN RAILWAY COMPANY.*

The power-station (figs. 1, 2, 3 and 4, plate xxiv.) situated at Park Royal, beside the Great Western Railway Company's line to High Wycombe, occupies about one-sixth of the ground available, and it is so designed and placed as to enable five other similar stations to be built as the demand for power increases. The three-phase current is generated at from 6,300 to 6,600 volts and 50 periods per second. It is transmitted from Park Royal by six high-tension, three-core, paper-insulated, lead-covered and armoured cables, laid underground on the solid system to the first sub-station at Old Oak Common. From Old Oak Common sub-station five high-tension main feeders are carried to Westbourne Park, where they branch in a special inspection-chamber, four feeders going to a sub-station at Royal Oak, and three going to a sub-station near Shepherd's Bush. The distance from Park Royal to Old Oak Common is about 1 mile, to Royal Oak about 4½ miles, and to Shepherd's Bush about 5 miles (fig. 5).

In the sub-stations the greater part of the three-phase current is transformed by motor-generators from 6,500 volts to 600 volts direct current; and at this pressure it is distributed from the Royal Oak and Shepherd's Bush sub-stations by concentric lead-covered cables to the conductor-rails of the Hammersmith and City Railway. At Old Oak Common and at Royal Oak, the direct current at 600 volts is also distributed for lighting the locomotive-sheds, carriage-sheds, goods-yards, and offices, and part of Paddington station. A part of the three-phase supply to each sub-station is distributed at the full pressure of 6,500 volts to eleven distributing centres, where it is transformed down by static transformers to either 220 or 110 volts. At this pressure, the alternating current is used for arc and incandescent lighting and small motor-work throughout the stations, goods-yards, offices, and hotel, at or near Paddington, and on the Hammersmith and City Railway.

* *The Railway Times*, 1906, vol. lxxxix., page 765.

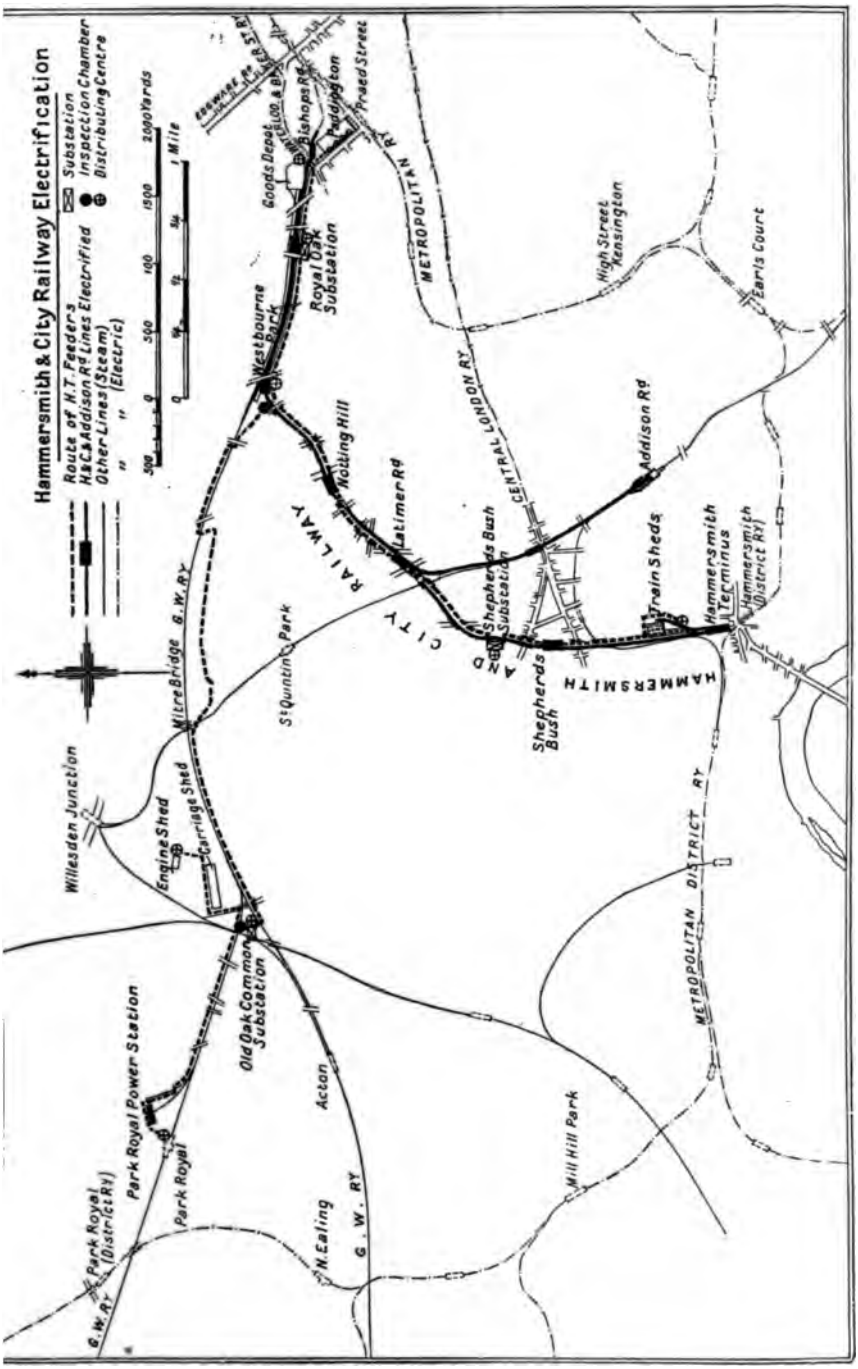

FIG. 5.—PLAN OF HAMMERSMITH AND CITY RAILWAY.

Generating Units.—The main engine-room is built in three bays. Four three-phase generators of 750 kilowatts and engines are placed in line in each outer bay (fig. 6, plate xxv.), making altogether a total capacity of 6,000 kilowatts. The three-phase generators, built by the Electric Construction Company, are of the ordinary rotating field-magnet type, star-connected, but the centre-point is not permanently earthed. They have an overload capacity of 25 per cent. for one hour. The armatures can be slid sideways for inspection or repair. Each generator is direct-coupled to a Belliss & Morcom triple-expansion side-by-side engine running at 250 revolutions per minute. The governor of each engine is controlled by an electric motor from the switchboard gallery, for adjusting the load between sets running in parallel. An electrically controlled emergency-switch is also fitted to each engine, so that under emergency steam could be entirely cut off by the switchboard hand.

Auxiliary Plant.—The excitation-current for the main three-phase generators is obtained from two auxiliary sets and two batteries. One of these exciters is steam-driven and the other is motor-driven. The exciter-generators are similar machines, each of 150 kilowatts output at 220 volts. The auxiliary Belliss & Morcom compound engine, with two cranks, is run at 428 revolutions per minute. The motor driving the second exciter-set is a three-phase induction-motor designed for the full high-tension pressure of 6,500 volts. The batteries, forming a stand-bye for the excitation-supply, are worked in parallel with the exciter-generators, with motor-driven boosters for charging them from the omnibus-bars. Each exciter-generator, with its battery, can be worked by itself, and used for exciting any or all of the main generators when required. Two auxiliary three-phase generators of 150 kilowatts output, one steam-driven and the other motor-driven, generate three-phase current at 650 volts. The steam-engine is a duplicate of that driving the exciter-set described above, and the motor driving the three-phase auxiliary generator is a direct-current motor, taking its supply from one of the exciter switchboards.

The auxiliary three-phase supply at 650 volts is used principally for driving the various motors throughout the generating station, such as the circulating pumps for the condensers, the

automatic stokers on the boilers, the coal-conveyors, etc. A three-phase switchboard for the auxiliary supply is placed on the switchboard-gallery between the two main high-tension switchboards. Two sets of step-down transformers are provided, by which all the auxiliary three-phase plant can be driven when necessary from the main high-tension supply without running any of the auxiliary sets. The motor-driven three-phase generator can be used when required for charging feeders, or it can be run backwards, taking current through the transformers from the high-tension supply or direct from the auxiliary supply, and delivering direct current to the exciter switchboard.

Switchboards.—Two main high-tension three-phase switchboards are placed at the western end of each main engine-room bay. The two boards can be worked independently of each other, or can have their omnibus-bars connected for working in parallel. Each switchboard has a duplicate set of main omnibus-bars and high-tension synchronizing omnibus-bars, used for testing and charging the feeders as well as for synchronizing the generators. Any generator or feeder can be connected to either set of main omnibus-bars. The circuit from each main generator and each feeder is branched and connected to two oil-break automatic switches, each directly connected to one set of the main omnibus-bars. By this arrangement the two automatic switches are used as selector-switches as well, and are also a stand-bye to each other. The machines can be changed from one set of omnibus-bars to the other, through the machine's own switches or through a separate bar-coupling switch. In order to avoid any mistake in synchronizing with the wrong set of omnibus-bars when switching in a generator, a system of mechanical interlocks is fitted at the back of the control-panels.

The high-tension part of the switchboard consists of a steel framework filled in with stone slabs. Each circuit runs from the bottom to the top of the switchboard, and is separated from the others by vertical stone partitions. The switches, transformers, etc., of each circuit are further separated from each other by four horizontal partitions, dividing the whole structure into a set of fireproof cells. Iron doors are fitted to the back of the cells, giving access for inspection and cleaning. The control switchboard is placed on a gallery, and slightly in front of the

high-tension switchboard. The main switches are worked by rods and cranks from the control panels. All the instruments are placed on the control panels, and are worked off transformers, so that all connections on these panels are low tension.

Immediately in front of the control panels are placed the main generator field-regulating resistance columns, and also a set of signal columns and indicators by which the switchboard attendant can communicate with the driver of the engine. At the end of the centre bay of the engine room, the auxiliary three-phase switchboard, working at 650 volts, is placed on the same gallery as the main switchboard control panels. This auxiliary board is also fitted with two sets of omnibus-bars, and is connected through step-up transformers with each of the main high-tension boards. The supply is, however, normally obtained from the two three-phase auxiliary generators. Feeders are taken from this switchboard to the various three-phase motors throughout the power-house. Two direct-current exciter switchboards working at 220 volts are placed, one at the end of each of the main engine-room bays, at the floor-level, immediately under the front of the main switchboard gallery. The two exciter switchboards can be worked separately or in parallel, and each is connected to an auxiliary direct-current generator and to a storage-battery. The supply for the excitation of the main and auxiliary three-phase generators is taken from these switchboards, as well as feeders for working the direct-current crane-motors and the arc and incandescent lighting of the power-house.

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Boiler-house Plant.—The boiler-house contains ten Babcock & Wilcox water-tube boilers arranged in two rows of five. Each boiler is fitted with a superheater, and has sufficient heating surface to render the use of economizers unnecessary.

A main flue is carried at the back of each row of boilers to the eastern end of the boiler-house, where a cross flue, outside the end-wall of the boiler-house, connects the two main flues, which are carried into a square chimney 250 feet high and 12 feet across

Fig. 8.—Circulating Pipes.

internally. The working pressure of the boilers is 200 pounds per square inch. Each boiler is guaranteed to evaporate 19,200 pounds of steam per hour from and at 212° Fahr. The steam, as it leaves the boilers, is superheated 120° Fahr. Each boiler is

fitted with a mechanical stoker of the chain-grate type, worked from an overhead shaft. The shaft in front of each row of boilers is driven by a three-phase induction-motor working at 650 volts. Worm reduction-gear is used, and an arrangement of claw-clutches enables a spare motor to be brought into use when required, driving the shaft from the opposite end.

A duplicate set of feed-pipes is carried from the pump-room at the western end of the boiler-house in front of each line of boilers. These pipes are connected across the boiler-house at the eastern end, and also in the pump-room, so as to form a complete duplicate ring. The boilers and feed-pumps are connected to both rings, and the valves are so arranged that all water for the boilers can be measured by water-meters. The feed-pump suction-pipes are carried into two large hot-well tanks, in the basement of the boiler-house under the pump-room floor. The feed-pumps can also draw direct from the water-supply pipe, or from the circulating-water pipes from the cooling-tower tanks.

Coal-handling Plant.—Special steel wagons, holding 15 tons of coal, are shunted on to the siding over the large coal silo at the eastern end of the boiler-house (figs. 1 and 2, plate xxiv.). There are five wedge-shaped hoppers formed of reinforced concrete, below which is a tunnel running from end to end. The silo is built below rail-level, the ground having been excavated, so that the coal can be discharged by gravity from the wagons, made with bottom-doors.

Two tray-conveyors, placed in the tunnel under the hoppers, transport the coal from the bottom of any one of the hoppers to the boots of two vertical bucket-elevators, at the centre of the silo. The coal is raised in this way to a height of 50 feet above the boiler-house floor-level, where it is discharged into two bucket-conveyors running parallel to the centre-line of the boiler-house. Each tray-conveyor and bucket-elevator is driven by a three-phase induction-motor working at 650 volts. Each bucket-conveyor is driven by its own motor, and is not geared in any way to the elevator. Any surplus elevated coal returns by gravity to the bunkers. Each bucket-conveyor passes over a weighing machine, which automatically registers the weight of coal passed from the silo into the boiler-house. The bucket-conveyors run over a gantry from above the coal-siding into the

boiler-house, where they pass over a row of large steel bunkers, into which the coal is discharged. These bunkers are built over the boilers, and form a coal-store from which the coal falls by gravity through measuring boxes into the hoppers of the chain-grate stokers. The Klein coal-measuring boxes, one of which is placed in front of each boiler, are fitted with adjustable shutters for calibrating their capacity, and with counters for registering the number of times that each box is emptied. The bucket-conveyors, after passing over the coal-storage bunkers, pass down vertically through the pump-room end of the boiler-house to the basement, along which they return under the boiler-house floor. The ashes from the boilers are filled into the conveyors as they pass below the boilers, and are so taken back to the railway-siding, over which they are discharged into a large steel hopper, whence they can be discharged by gravity into wagons.

THE KNIGHT, BEVAN & STURGE WORKS OF THE ASSOCIATED PORTLAND CEMENT MANUFACTURERS (1900), LIMITED, NORTHFLEET, KENT.

These works comprize one of the largest and most up-to-date branches of the Associated Company, which was formed seven years ago, and includes the manufacturers of nearly all the principal brands of Portland cement made in this country.

The visitors witnessed the quarrying of the chalk on the extensive properties of the company, adjacent to the works, and the importation of the alluvial clay from the river Medway, where the company and their predecessors have purchased large supplies.

The estuaries of the Thames and Medway are acknowledged to be the cradle of the industry, and the origin of Portland cement dates back to 1824, when letters patent were obtained by Mr. Joseph Aspdin for this material, which was first made commercially at Northfleet, Swanscombe and Cliffe, at works which are now owned by the Associated Portland Cement Manufacturers.

At the washmills, the chalk and clay are amalgamated, in fixed and definite proportions, with about 43 per cent. of water, and the mixture leaving these mills is of such a fineness that 95 to 97 per cent. will pass through a sieve having 32,400 holes per square inch. The chalk consists of almost pure carbonate

of lime, and the clay of silicates of alumina and fine quartz-sand, the ratio of total silica to alumina being about 3 to 1. The materials thus reduced, and thoroughly amalgamated, are pumped to large storage-tanks, where the mixture is kept in continual motion, and settlement prevented until the material is transferred to the kilns for calcination. The whole of the process is under the direct control of the works chemists, who keep the composition of the mixture constant, and thus ensure a perfectly uniform and sound product.

In the second or chemical section of the manufacture, the water present naturally in the raw materials, together with that added for mixing purposes, is evaporated. The dry materials thus obtained are gradually heated up to a temperature of 2,800 to 3,000 degrees Fahr., at which temperature the whole of the carbonic anhydride of the chalk has been expelled, converting the chalk into lime; whilst the latter has entered into chemical combination with the silica and alumina of the clay, thus forming a double silicate of lime and alumina, which constitutes the principal factor of Portland cement clinker. Here again the greatest care is required during the process of calcination, so as to prevent the production either of an under-burnt or of an over-burnt product: the former being conducive to an unsound cement, and the latter to an over-burnt inert slag.

It follows that the method of calcination which permits of the maximum of control during the process should be productive of the first quality of cement clinker, and for this reason the modern method of continuous burning with rotary kilns has been found to excel all other more antiquated and intermittent methods.

The whole of the process on the rotary system is under the absolute control of the operator, who can regulate the quantity of raw material entering the kiln, the amount of fuel (pulverized coal) being injected to keep up the temperature, and the speed of rotation of the kiln, thus governing the output at will; and so the calcined clinker leaves the kiln in a stream of small particles, in which any variation of hardness is easily detected and immediately rectified.

One other important improvement obtained by this method of calcination is the exclusion from the clinker of practically all

atmosphere, becomes slow-setting, and that in proportion to the period of aeration; and it also improves in soundness by the neutralization of any particles of free lime present through the absorption of water and carbon dioxide (CO_2) from the atmosphere. This action is very imperfect, however, when cement is stored in bulk, and can only be in a measure successfully accomplished by continually turning over the cement and exposing fresh surfaces to aeration.

Practically the whole of the works are electrically driven, the main generating station consisting of four Belliss high-speed engines coupled direct to Westinghouse generators.

After inspecting the foregoing departments of the manufacture proper, the members visited the cooperages, where the necessary packages for export are made in special machinery, which is the subject of patents owned by the company.

ELECTRIC TRANSMISSION OF POWER AT THE WORKS AND COLLIERIES OF THE GRAND-HORNU, BELGIUM.*

By E. TROUSSART.†

The history of this electric plant is as follows:—

About 1895, an electric plant was installed for lighting and a certain amount of power transmission, using continuous current at 600 volts, and working the following:—

(1) Three electric locomotives of 20 horsepower each for narrow-gauge track 23½ inches (0·6 metre) wide, for the purpose of bringing the tubs from two pits to the third, where the screens are situated, the three pits occupying the apices of an isosceles triangle with 1,312 to 1,968 feet (400 to 600 metres) length of side.

(2) Numerous small motors, working hoists underground and at the surface, for various duties, and for the foundry.

(3) Two small geared pumps, one of 6 horsepower, forcing 220 gallons (1 cubic metre) of water per hour to a height of 262½ feet (80 metres) from the 2,560 to the 2,296 feet (780 to 700 metres) level at No. 12 pit; the other of 35 horsepower, forcing 8,000 gallons (36 cubic metres) of water per hour to a height of 525 feet (160 metres) from the 2,330 to the 1,804 feet (710 to the 550 metres) level at No. 7 pit.

The old direct-acting pump took the water from the 1,804 feet (550 metres) level.

The experience of this electric pumping plant, which had been working for 4½ years, has been satisfactory. The electric installation has gradually been extended more and more, to such a point that it is necessary to work it in stages, and to run the pumps on the night-shift.

At the commencement of the year 1900, it was decided to

* "L'Installation de Transport d'Énergie Électrique aux Usines et Mines de Houille du Grand-Hornu," *Publications de la Société des Ingénieurs sortis de l'École Provinciale d'Industrie et des Mines du Hainaut*, third series, 1904, vol. xiii., page 284.

† Translated by Prof. Henry Louis, M.A.

replace the old direct-acting pump, which was too weak and threatened to break down, by one single underground pump installed at a depth of 2,296 feet (700 metres). At this stage, however, it was considered advisable to put in a central electric station and to supply by means of it the following, namely:—

(*a*) Three winding-engines at pits Nos. 7, 9, and 12.
(*b*) Two fans of 200 horsepower each, at pits Nos. 2 and 8.
(*c*) Two pumps of 125 horsepower each.
(*d*) Motors for the screening plant, taking about 200 horsepower.
(*e*) Underground haulage, requiring about 100 horsepower.
(*f*) Machine-shops and repair-shops, requiring about 100 horsepower.
(*g*) Lighting and the plant worked by the existing continuous current, equal to 300 horsepower.
(*h*) Sufficient reserve of power.

Finally, it was decided to put in a main central station, and, provisionally, a subsidiary generating-station comprising a three-phase dynamo under the same conditions as those to be laid down at the main central station, which should have an effective power of 150 kilowatts at 1,250 volts, a periodicity of 47 alternations, and 185 revolutions per minute. It is placed in a side building and driven by belting from the reserve steam-engine of the subsidiary central station.

The electric generator is connected to four motors by means of an air-line 1,969 feet (600 metres) in length, together with a short length of underground cable beneath the sorting-house. The motors of the screening plant (2 in number) work the screens and conveyors; their power is equal to 50 horsepower at 335 revolutions per minute. One motor drives an endless-chain haulage, 1,148 feet (350 metres) in length, and another an aërial ropeway 2,625 feet (800 metres) in length. Each of these motors is of 25 horsepower at 335 revolutions per minute. These respective motors are of the same type, and completely interchangeable. Recently, three triphase motors of 15 horsepower each have been added.

The rotors of these machines have starting-rings connected with a fluid resistance. Once the motor has attained its full speed, it is possible to short-circuit the rotor, so as to get the best possible efficiency. This installation has been working since December, 1902, and in spite of great difficulties of working, due to such causes as dust, damp, and overload, the motors have given no trouble whatever.

Central Electrical Station.

As already stated, this central station is for the present sufficient to work the whole of the mine and works of the Grand-Hornu. It is placed near pit No. 7.

Boilers.—The boiler-house, 105 by 56 feet (32 by 17 metres), contains at present six semi-tubular boilers, having each 2,153 square feet (200 square metres) of heating-surface, blowing off at a pressure of 142 pounds per square inch (10 kilogrammes per square centimetre). Space has been reserved for eight boilers altogether. The evaporative power amounts to 6,610 pounds (3,000 kilogrammes) of steam per hour, so that with five boilers working, 2,500 horsepower can be produced, which is sufficient for the needs of the moment.

The safety appliances comprise two Lethuillier-Pinel valves with gradual discharge and blow-off pipe, float-indicator, whistles showing excess and deficiency of water, watergauge, and pressure-gauge. Each boiler has a superheater of the Hering system of Nuremberg, raising the temperature of the steam to 536° to 572° Fahr. (280° to 300° Cent.). The employment of this superheater is fully justified, for experiments have shown a saving of fuel amounting to 16 per cent. The superheater consists essentially of two series of horizontal worms made of steel tubes 1·38 inches (35 millimetres) in internal diameter, terminating in collectors of cast steel, placed vertically at the four corners on the outside of the block of masonry of the superheater. The two front collectors communicate with the steam-dome; those at the back with the steam-pipe.

The boilers are fired by mechanical firers made by the Economical Firing Company (Spaarfeuerungs Gesellschaft) of Düsseldorf. The coal is teemed into a brick cellar, and raised by a bucket-chain into the trough of an archimedean screw conveyor, which conveys it to the hoppers of the fire-places; the coal is then pushed forward, over a front fireplate and the interior inclined wall of the doors, on to the firebars by a rectangular piston, the stroke and speed of which can be regulated as desired. There are two pistons and hoppers for each fire-place. The latter consists of steel grates, which have a slow movement produced by a cam keyed to a shaft situated in front of and outside the fire-place. This movement advances all the firebars simultaneously, and then

brings them back successively to their original position. The first movement advances the coal, the second clears the grates and discharges the fine ashes. Ordinary firedoors are provided, so as to enable hand-firing to be employed should any accident happen to the machinery. The ashes are picked up mechanically by a chain transporter, which drops them directly into a truck. A 15 horsepower triphase motor works the firebars and the transporters for coals and ashes. The advantages of these grates are as follows:—(1) They consume the smoke almost entirely, the coal being first distilled and the gases thus generated subsequently burnt. (2) They effect a saving of coal, owing to the complete combustion produced by working with doors always closed, and by the rational distribution of fuel. (3) The bars are cleaned mechanically without stopping the firing. (4) Combined with mechanical transport, they keep the boiler-house neater and cleaner. (5) They produce economy of labour, two men sufficing for eight boilers. The boilers are fed by a Worthington pump and a 15 horsepower electric pump. The steam is conveyed to the engines by drawn-steel tubes 10 inches (25 centimetres) in diameter, covered with Magniette composition. Each boiler can, of course, be shut off independently from the main steam-pipe. There is no steam reservoir.

Central Station.—This lies at the side of the boiler-house, separated from it by a passage of 20 feet (6 metres), and is 69 by 79 feet (21 by 24 metres), with a wing 69 by 20 feet (21 by 6 metres). The engine-house is supplied with a 25 tons hand-travelling crane, which itself weighs 18 tons.

First Group of Generators.—A horizontal tandem-compound condensing steam-engine drives directly a triphase generator. The engine has balanced valves of the Sulzer-Carels type, with cut-off of the high-pressure cylinder regulated by the governor and fixed cut-off on the low-pressure cylinder. The dimensions of the engine are as follows:—

Diameter of the high-pressure cylinder, 31½ inches (0·8 metre).
Diameter of the low-pressure cylinder, 51 inches (1·3 metres).
Stroke, 53 inches (1·35 metres).
Velocity, 88 revolutions per minute.
Piston-velocity, 13 feet (3·96 metres) per second.
Diameters of the piston-rods, 6¼ and 7 inches (165 and 180 millimetres) respectively.

With an initial pressure of 128 pounds per square inch (9 kilogrammes per square centimetre), and at cut-offs of

3 per cent.,	5 per cent.,	16 per cent.,	36 per cent.,	it is capable of developing
625	825	1,340	2,100	indicated horsepower, respectively, with a corresponding consumption of
12 pounds (5·5 kilogrammes)	11½ pounds (5·25 kilogrammes)	11½ pounds (5·25 kilogrammes)	14 pounds (6·5 kilogrammes)	of steam superheated to 500° Fahr. (260° Cent.).

The condenser works by injection, is placed below the cross-head guides, and is worked by means of a vertical connecting-rod and bent lever. The governor is arranged to control the engine, so that when all the load is taken off the speed shall not increase by more than 6 per cent., and shall be brought back to 3 per cent. in 20 seconds. Furthermore, a special arrangement shuts off all the steam, destroys the vacuum of the condenser, and stops the engine in case of any accident to the governor or to the valves. The co-efficient of regularity is $\frac{1}{200}$.

It need hardly be said that all the oiling arrangements are of the most perfect type. The engine is started by a little steam turning-gear working directly upon the rim of the flywheel. Running empty and without current, the engine absorbs about 100 horsepower. The triphase generator works at 1,250 volts, 47 alternations, or 23·5 periods, and is capable of giving out normally 2,000 kilo-volt-amperes, or 1,600 kilowatts effective with cos. $\phi = 0{\cdot}8$. (The periodicity has been fixed to suit the speed of the winding-engine.) The rotor is in four pieces, keyed on a shaft, 26¾ inches in diameter (0·68 metre), and, mounted complete, weighs 75 tons (75,000 kilogrammes). It carries thirty-two poles with induction-coils. The weight of the copper in these coils amounts to nearly 5 tons (5,000 kilogrammes). The stator, 16¼ feet (4·95 metres) in the clear, with a width of iron for the magnets of 31½ inches (800 millimetres), contains in 480 recesses the high-tension coils formed of bars of copper insulated by micanite. The stator is in two pieces, and weighs altogether 38½ tons (38,500 kilogrammes). The amount of clearance between the rotor and stator is 0·3 inch (7·5 millimetres).

The efficiency of the alternators (cos. $\phi = 0{\cdot}8$) is 95 per cent. at full load, 93 per cent. at half-load, and 88 per cent. at quarter-load. The fall of tension between running light and running at full load is at most 7 per cent.

The second group of generators has a power double that of the first; that is to say, it consists of two tandem-compound engines of the same dimensions and same construction, acting at an angle of 90 degrees on the same shaft. Each engine has its separate condenser. This engine, therefore, at 80 revolutions per minute, with cut-offs of

3 per cent.,	5·5 per cent.,	16 per cent.,	36 per cent.	can evolve
1,250	1,650	2,680	4,180	indicated horsepower respectively, with a steam-consumption of
12 pounds (5·5 kilogrammes)	11½ pounds (5·25 kilogrammes)	11½ pounds (5·25 kilogrammes)	14½ pounds (6·5 kilogrammes)	of steam per horsepower, superheated to a temperature of 500° Fahr. (260° Cent.), at a pressure of 9 atmospheres.

The steam consumption is guaranteed, the guarantee being subject to a heavy penalty, which increases for every ½ pound (200 grammes) of additional steam consumed. The engine running empty absorbs 210 horsepower. The rotor of the electric generator is keyed between the two cranks, on a shaft 29½ inches (0·75 metre) in diameter; it is in four parts, and weighs 100 tons (100,000 kilogrammes) when complete. It consists of a cast-iron flywheel, on the rim of which is keyed the laminated magnetic crown which carries the thirty-two pole pieces. The thirty-two magnetizing coils contain 10 tons (10,000 kilogrammes) of copper. The enormous weight of this rotor flywheel has been so calculated as to store momentum equal to the energy necessary for the simultaneous starting of the three winding-engines. The engine is started by a little steam-starter acting upon the iron crown. The stator, 24 feet (7·30 metres) in the clear, with a width of iron magnets equal to 23½ inches (600 millimetres), has 384 recesses for the high-tension coils. The total length of the machine is 33 feet (10 metres). The frame is in four pieces, and weighs altogether about 56 tons (56,400 kilogrammes). The clearance is 0·55 inch (14 millimetres). The guaranteed efficiency of this generator is 97 per cent. at full-load, 93 per cent. at half-load, and 91 per cent. at quarter-load, with a value of $\cos. \phi = 0{\cdot}8$. The fall of tension between running empty and running at full load must not exceed 7 per cent. The machine can withstand overloads of 15 per cent. with a fall of $\cos. \phi = 0{\cdot}75$. The capacity of this generator is double that of the first, or 4,000 kilo-volt-amperes, equal to 3,200 kilowatts, with $\cos. \phi = 0{\cdot}8$.

The central station has a capacity, therefore, of 6,280 horsepower, or 12·5 horsepower per square metre (10¾ square feet) of floor space of the building. The 4,000 horsepower engine is sufficiently powerful to furnish energy to the whole installation, and will suffice to start simultaneously the three winding-engines, so that normally this will be the only portion working. The smaller unit of 2,000 horsepower is in reserve. As there is greater danger of an accident to the steam-engine than to the generator, there are altogether three identical steam-engines, of which two are coupled to the same generator. In case, therefore, of an accident to one of the two tandem-compound engines, the connecting-rod can be uncoupled, working with one side only, the large motor working at half-load, which can be connected directly with the smaller unit, giving together the 4,000 horsepower required. In case of any accident to the alternator, which would be a very extraordinary event, the small unit can be made to do the work by spacing it and starting the winding-engines successively. This can be done, seeing that each driver has before him a voltmeter and an ammeter. The voltmeter will indicate a certain momentary fall of current-tension, lasting for a few seconds, when any of the winding-engines are started.

Rotary Transformer.—In addition to these two groups of steam-driven generators, there is at the central station a rotary transformer, consisting of three dynamos keyed to the same shaft:—

(*a*) In the centre, a triphase motor of 350 horsepower and 460 revolutions per minute.

(*b*) On the one side, a continuous-current dynamo of 90 kilowatts and 240 volts, acting as exciter for the alternators, and capable of supplying the general lighting. This dynamo is so constructed that, by employing a tension-divider, it is possible to work the lighting installation at 2×110 volts, with one dynamo.

(*c*) On the other side, a continuous-current dynamo of 135 kilowatts at 600 volts to supply energy to the existing installation, as also a shunting locomotive of 100 horsepower for the normal gauge of rail. Finally, a little battery of Pollak accumulators of 135 ampere-hours has been installed, to be used in case of need for lighting, and when it is necessary to start the alternators at times when the works are completely stopped.

The switchboard is a very important part of the central station, and is of especial interest to electricians. It consists of three floors, one above the other:—

(*a*) The upper floor-level, with a gallery 41 feet (12·5 metres) long, forms the portion visible from the inside of the engine-room. It consists of twelve panels of white marble, in front of which are placed all the measuring instruments and the switches for the continuous current, handles for working regulators, and the oil-switches of the large dynamos, as also the handles for working the distant switches of the high-tension triphase circuits. Behind it there is a space 8¼ feet (2·5 metres) wide, in which are placed the connections, safety-fuses for the continuous current, the regulators for exciting the continuous and triphase dynamos, and a little appliance for charging the battery.

(*b*) The intermediate level is accessible only by a staircase opening behind the switchboard, and encloses the high-tension apparatus. The entry to this place will be strictly forbidden during working hours, as it is well known that any contact with conductors of a 1,250 volts current is sufficient to cause death.

(*c*) The third level underground below the engine-room contains the bars and cables connecting the dynamos and the starting-points of the underground cables.

The current collected from the fixed terminals of the alternators is brought to the second level of the switchboard by aluminium bars carried on insulators and enclosed in metallic sheathing, so as to prevent any accidental contact with them. Between the three omnibus-bars for 1,250 volts and each of the generators is placed an oil-switch worked from the upper-level of the switchboard by means of a chain, as also a tripolar switch worked by hand. The triphase measuring-transformers make it possible to observe at a perfectly safe low tension of 60 volts the appliances of the switchboard, voltmeter, ammeter, and watt-meter, carried upon marble slabs. Each branch from the omnibus-bars includes a hand-switch and a special oil-switch, which is automatic, and can be worked electrically by means of a double contact (one to close it, the other to open it), situated on the front of the marble switchboard. This may require some explanation. Outside the oil-reservoir of these automatic switches are two electromagnets excited by the continuous current at 240 volts. One of

these can be made to attract its armature to close the switch; the other can be made to disengage a catch, and the switch opens automatically by its own weight. By means of a contact-maker, it is possible to send the current through one or other of these electro-magnets as required. Furthermore, the opening-catch is automatically brought into play by a relay whenever the current exceeds a definite amount. Whenever these automatic switches come into play, an alarm-bell gives notice to the man in charge of the switchboard. This man can also close the circuit without going down into the underground cellar, where he would be exposed to great danger.

Cables.—From the central station seven groups of cables run underground. They are treble cables insulated by special paper, sealed in lead, and armoured with steel wires or tapes, and are as follows:—

(1) To the winding-engine at No. 7 pit. Length of cable, 164 feet (50 metres); section of copper $0{\cdot}118 \times 0{\cdot}48^2$ inches (3×310^2 millimetres).
(2) To the winding-engine at No. 12 pit; length, 1,476 feet (450 metres); section the same.
(3) To the fan-motor at No. 8 pit; length, 623½ feet (190 metres); section of copper $0{\cdot}118 \times {\cdot}077^2$ inches (3×50^2 millimetres).
(4) To the Fan at No. 2 Pit; length, 394 feet (120 metres); section the same.
(5) To the screening plant, etc.; length, 394 feet (120 metres); section the same.
(6) To the underground pump; length, 2,690 feet (820 metres); section $0{\cdot}118 \times 0{\cdot}054^2$ inches (3×35^2 millimetres).
(7) To the rotary transformer to the central station; section $0{\cdot}118 \times 0{\cdot}155^2$ inches (3×100^2 millimetres).

These cables are simply placed in a trench 23½ to 31½ inches (60 to 80 centimetres) deep, covered by dry brick, and then filled in. Their position is carefully marked by stone posts. Under the public road, the cables pass in a culvert formed by an old boiler-flue.

Cooling.—The condensers of the engines require 50 gallons (225 litres) per horsepower hour, or for the normal load of 2,680 horsepower about 128,000 gallons (580 cubic metres) of water per hour. It was found not to be possible to maintain a regular supply of water to the condensers, and it was accordingly decided

to instal a cooling-appliance, which only required to be supplied with sufficient water to make up the loss by evaporation. This cooling-appliance is an immense pond with sloping sides, measuring 40 by 80 feet (12 by 24 metres) at the bottom, and 56 by 95 feet (17 by 29 metres) at the surface of the ground, with a total depth of 20 feet (6 metres). In the bottom there are always 64,000 gallons (290 cubic metres) of water to a depth of 40 inches (1 metre). Over the pond is erected from its bottom a huge wooden shaft 72¼ feet (22 metres) in total height, rising 56 feet (17 metres) above the surface, measuring at the base 33 by 72¼ feet (10 by 22 metres) and at the top 16½ by 46 feet (5 by 14 metres). The overflow from the condensers is brought to the ground-level, passes through a grease-extractor, then runs through a series of wooden canals of decreasing dimensions, and is finally allowed to drop in spray over a series of baffle-plates of inclined planks. The chimney, by introducing a current of fresh air, draws away the steam. The apparatus is calculated for cooling 128,000 gallons (580 cubic metres) of water per hour with an external temperature of 68° Fahr. (20° Cent.), the water leaving the overflow at 140° Fahr. (60° Cent.). The cooling-appliance is to bring this temperature down to 86° Fahr. (30° Cent.).

The Winding-engine (plate xxvi., figs. 1, 2, 3 and 4).—The most interesting portion of the installation is without doubt the electric winding-engine. Two identical winding-engines have been laid down at pits Nos. 7 and 12, that at No. 7 undergoing its tests at the time when the paper was written. A similar engine, but rather less powerful, is intended for pit No 9. The new electric winding-engine for pit No. 7 is placed directly behind the steam winding-engine which it is to replace, in a new engine-house 49¼ by 52½ feet (15 by 16 metres). The winding capacity is 56 tons per hour from a depth of 3,280 feet (1,000 metres); 38 seconds are allowed for changing tubs, but by shortening this time it will be possible to increase the capacity of the machine. The actual depth of the shaft is, however, only 2,330 feet (710 metres) at present.

The following figures have been taken as a basis for calculation:—

Depth, 3,280 feet (1,000 metres).
Useful live load, 5,732 pounds (2,600 kilogrammes; six tubs).
Weight of tubs, 2,778 pounds (1,260 kilogrammes).
Weight of cage, 4,410 pounds (2,000 kilogrammes).

The rope is a flat tapering rope of aloes, of decreasing section, having the following dimensions:—

Lengths of Sections in		Thicknesses in		Weight in		Weights per	
Feet.	Metres.	Inches.	Millimetres.	Pounds.	Kilogrammes.	Foot.	Metre.
						Pounds.	Kilogrs.
0- 394	0- 120	1·97-1·89	50·00-48·00	3,864	1,755	9·81	14·65
394- 720	120- 220	1·89-1·81	48·00-46·00	3,030	1,375	9·21	13·75
720-1,050	220- 320	1·81-1·73	46·00-44·00	2,755	1,250	8·57	12·50
1,050-1,380	320- 420	1·73-1·65	44·00-42·00	2,404	1,090	7·30	10·90
1,380-1,705	420- 520	1·65-1·55	42·00-39·50	2,035	925	6·19	9·25
1,705-2,030	520- 620	1·55-1·42	39·50-36·75	1,958	890	5·96	8·90
2,030-2,360	620- 720	1·42-1·38	36·75-35·25	1,848	840	5·62	8·40
2,360-2,690	720- 820	1·38-1·30	35·25-33·00	1,815	825	5·52	8·25
2,690-3,020	820- 920	1·30-1·30	33·00-33·00	1,786	812	5·44	8·12
3,020-3,345	920-1,020	1·30-1·26	33·00-32·90	1,690	768	5·14	7·68
3,345-3,675	1,020-1,120	1·38-1·29	33·90-32·70	1,562	710	4·75	7·10

Mean weight, 6·7 pounds per foot (10 kilogrammes per metre).
Mean thickness, 1·614 inches (41 millimetres).

The diameter of the empty reels is 1·4 metres (56 inches) the initial radius 47¼ inches (1·2 metres), the final radius 12¼ feet (3·73 metres), or 24½ feet (7·46 metres) external diameter of the coiled-up rope. The number of revolutions is 64 for each hoist. It should be possible to make 25 lifts per hour; the time of a wind should therefore be 144 seconds, less 38 seconds for changing tubs, leaving 106 seconds for the wind properly speaking. The diagram of velocities of the ascending cage can therefore be represented by fig. 1.

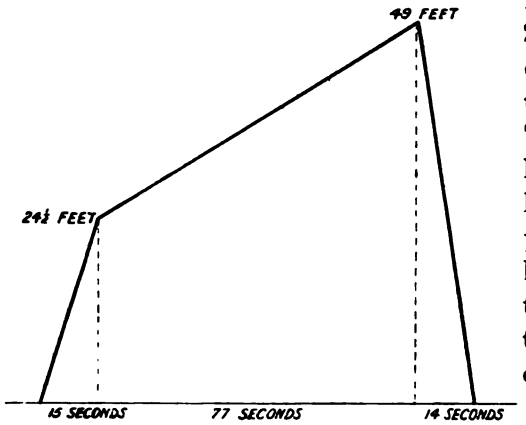

FIG. 1.—DIAGRAM OF VELOCITIES OF ASCENDING CAGE.

The rate of acceleration can be clearly determined and easily realized in practice: 14 seconds has been allowed as being admittedly sufficient to avoid jerks. The number of revolutions of the motor has been calculated at 42 per minute for the period of constant velocity. It is this speed of the winding-engine that

ed on the high-speed line from Berlin to Zossen with a num power of 3,000 horsepower. It has been applied to the of Preussen No. II colliery, where it has been working per- fourteen months. The mode of construction is indicated

ternal vessel, having a capacity of 108 cubic feet (3 are suspended the sheet-iron electrodes, supported n order to insulate them from the body of the ap- nected with the three phases of the rotor. The f soda, is pumped into this reservoir by means l pump worked by a 3 horsepower triphase ing. As long as the intake-valves of the uid runs freely into an external vessel con- g a cooling-tube. If the valves are closed, the liquid rises and closes the circuit between the three phases of the rotor, which begins to turn slowly. The higher the level to which the liquid rises, the deeper are the electrodes plunged into it, the less is the resistance, and the nearer does the motor approach to its normal velocity, reaching this speed when the level of the liquid reaches an overflow, which is always open. The period of acceleration can easily be regulated once for all by the rate of discharge of the pump by means of a valve placed in the delivery-pipe. By this means the engine-driver can never start too rapidly; and, in starting, jerk upon the ropes is entirely prevented. The levers actuate the valves of the starting switch and of the reversing switch (to which they are connected by the same lever worked by the engineer), turn the current into the stator, and close the valve of the starting-switch; so that one simple movement of the lever, forward or backward from its vertical position suffices to start the engine. An adjustable overflow is arranged at the bottom of the reservoir, so that the iron plates shall con-

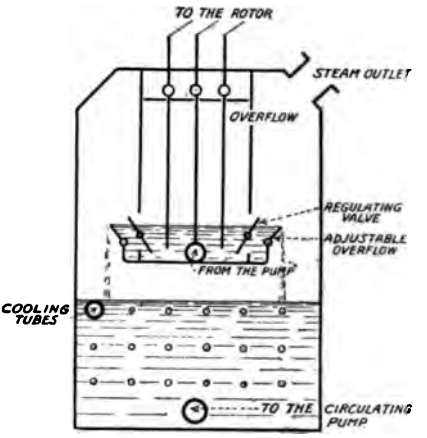

FIG. 3.—LIQUID-RESISTANCE STARTER.

has determined the rate of alternations to be allowed for the installation. To determine the power required to start the engine, the mass to be accelerated has been calculated by the following (fig. 2).

PD^2 of the two drums and the brake-drum	220,000
PD^2 of the rotors	100,000
PD^2 of the pulleys	16,000
PD^2 total	1,000,000

Taking friction at 25 per cent., the effective power required for the winding-motor will be shown by the following diagram (fig. 2):—

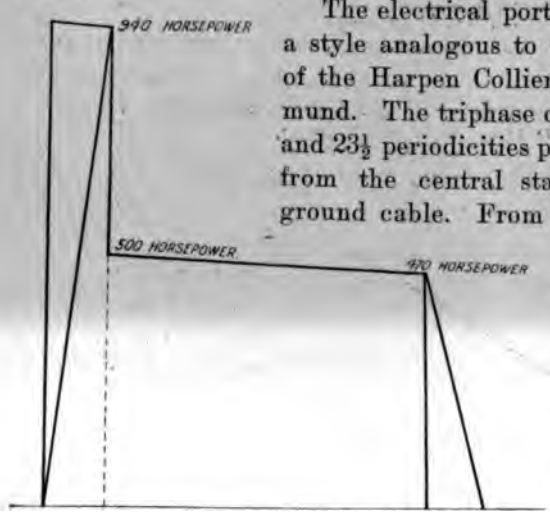

FIG. 2.—DIAGRAM OF EFFECTIVE POWER OF WINDING-MOTOR.

The electrical portion is carried out in a style analogous to that of Preussen II of the Harpen Colliery, Limited, of Dortmund. The triphase current of 1,250 volts and 23½ periodicities per second is brought from the central station by an underground cable. From the tripolar safety-fuses the three bars taking the current pass into an oil-switch, which acts as a safety-switch; then through the reversing mechanism to the fixed terminals of the stator. The stator is made up of two lateral cast-iron checks, bound firmly together by hollow stays, which results in a very much lighter stator than would otherwise be the case. It has an inside diameter of 12¼ feet (3·70 metres), and a width of iron of 25½ inches (650 millimetres), and weighs 16 tons. The clearance between stator and rotor is 0·128 inch (3·25 millimetres). Any wearing of the bearings can be taken up by lowering or raising the stator by means of micrometer screws. The rotor weighs 13 tons. The induced current is taken up from three cast-iron rings by brushes of very soft brass; it is carried directly to the liquid-resistance starter, which serves to start and regulate the speed of the engine. This appliance, which is a patent of the General Electric Company, has been

tested on the high-speed line from Berlin to Zossen with a maximum power of 3,000 horsepower. It has been applied to the engine of Preussen No. II colliery, where it has been working perfectly for fourteen months. The mode of construction is indicated in fig. 3.

In an internal vessel, having a capacity of 108 cubic feet (3 cubic metres), are suspended the sheet-iron electrodes, supported upon porcelain in order to insulate them from the body of the apparatus, and connected with the three phases of the rotor. The liquid, a solution of soda, is pumped into this reservoir by means of a little centrifugal pump worked by a 3 horsepower triphase motor constantly running. As long as the intake-valves of the vessels are open, the fluid runs freely into an external vessel containing a cooling-tube. If the valves are closed, the liquid rises and closes the circuit between the three phases of the rotor, which begins to turn slowly. The higher the level to which the liquid rises, the deeper are the electrodes plunged into it, the less is the resistance, and the nearer does the motor approach to its normal velocity, reaching this speed when the level of the liquid reaches an overflow, which is always open. The period of acceleration can easily be regulated once for all by the rate of discharge of the pump by means of a valve placed in the delivery-pipe. By this means the engine-driver can never start too rapidly; and, in starting, jerk upon the ropes is entirely prevented. The levers actuate the valves of the starting switch and of the reversing switch (to which they are connected by the same lever worked by the engineer), turn the current into the stator, and close the valve of the starting-switch; so that one simple movement of the lever, forward or backward from its vertical position suffices to start the engine. An adjustable overflow is arranged at the bottom of the reservoir, so that the iron plates shall con-

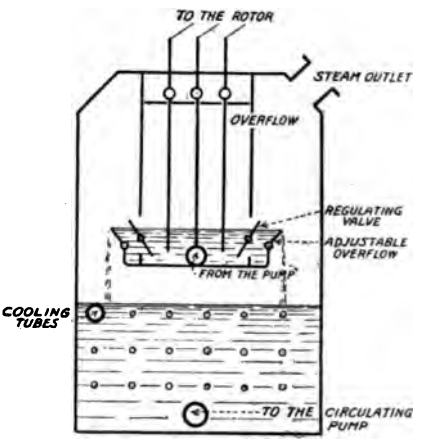

FIG. 3.—LIQUID-RESISTANCE STARTER.

stantly dip a little distance into the solution to enable the motor to start as soon as the current is sent into the stator and to avoid sparking at the edges of the iron plates. Moreover, the depth of this first bath can be regulated as desired, so as to be able to start at variable speeds; for instance, when hoisting light loads.

Experience at Preussen No. II colliery has shown that these starting-switches enable any desired speed to be attained with any desired load, and that these speeds can be maintained without difficulty. Moreover, the machine is very easily handled, and the starting is very smooth and without jerk.

All necessary safety appliances have been attached, namely:

(1) A progressive brake for normal running, worked by means of an ordinary brake-lever. At No. 7 pit steam has been used for the brake, as this pit is only 65¾ feet (20 metres) away from the boilers. At No. 12 pit, air compressed to four atmospheres by a 6 horsepower motor is employed.

(2) A safety-brake, with counterpoise, to be worked by the engineer by means of a pedal, which will at the same time open the safety-switch. This brake will only be used in cases of accident in the shaft or to the engine.

(3) A vertical depth-indicator, with double screw, shows the position of the cages in the pit and signalizes their arrival within 98½ feet (30 metres) of the surface.

(4) This indicator also forms an apparatus to prevent overwinding. When the cage has risen 1 or 2 yards (1 or 2 metres) above the banking-out level, as may be desired, the safety-switch is automatically opened, so that no current passes to the motor, whilst the steam brake immediately stops the engine.

(5) There is a retarding apparatus, which automatically brings back the starting-lever to such a point that the cage can only arrive at the banking-out level at a very slow speed—1 yard (1 metre), for example—whenever the machinist for any cause whatever may neglect to do his work. This retarding apparatus can be easily regulated for raising or lowering materials or men, so that the moment in which the starting-lever is acted upon may be delayed.

(6) If for any cause whatever the current should fail, an electro-magnet immediately loses its power; its armature drops, and, in falling, throws over levers which work the safety-switch and put on both brakes.

(7) A Karlik tacheograph registers the velocity of the engine, and is combined with an electric alarm-bell, which indicates the maximum speed when hoisting men. A column, carrying a voltmeter, ammeter, and pressure-gauge for the brake, is within full sight of the engineer. Owing to these combinations of safety-appliances, very simple in themselves, and only applicable when electricity is employed as the motive power, the safety of the winding plant in working is guaranteed. It must not be forgotten that the triphase-motor can sustain without difficulty considerable overloads, limited by the automatic switches of the central station. Finally, the engineer has before him:—(1) A lever, the appearance of which is just the same as the reversing lever of a steam-engine, but much easier to work, there being only one lever to be moved in one direction or the other; (2) a brake lever; (3) a lever regulating the overflow-valves, to be shifted before slow starting with light loads, as, for instance, when men are riding; (4) the pedal of the safety-brake; and (5) a little lever to modify the moment of coming into action of the retarding apparatus.

Underground Pump (plate xxvii., figs. 1, 2, and 3).

The underground pump is placed at a depth of 2,330 feet (710 metres) in an arched chamber 29½ feet (9 metres) long, 14 feet (4·25 metres) wide, and 11½ feet (3·5 metres) maximum height. A little travelling-crane has been put in to facilitate the erection of the pump. The roof of the engine-room is supported by a series of complete sets of I iron 6 by 6 inches by ½ inch (150 by 150 by 14 millimetres), placed 20 inches (0·5 metre) apart, the spaces between being filled with brick arches. The foundation of the pump is 6½ feet (2 metres) deep, of a single block of concrete, stiffened with steel rails. The pumping-plant consists of a triphase motor of 125 horsepower and 170 revolutions per minute, attached directly to a Riedler pump, capable of forcing 8,800 gallons (40 cubic metres) per hour to a height of 2,330 feet (710 metres). The differential pistons are 4 and 5¾ inches (103 and 146 millimetres) in diameter respectively. The mean stroke is 10 inches (0·25 metre), giving a mean piston-speed of 26⅓ inches (0·67 metre). The current is conveyed by a triple-armoured cable of 0·118 by 1·38 inches (3 by 35 millimetres) cross-section, along the walling of the winding-

FLORENCE COAL AND IRON COMPANY, LIMITED.*

By an unfortunate error, the description of Florence Colliery, visited by the members of The Institution of Mining Engineers during the course of their Annual General Meeting, held at Hanley, September 12th, 13th and 14th, 1906, was inserted under the heading of the "Stafford Coal and Iron Company, Limited," instead of the "Florence Coal and Iron Company, Limited."

DISCUSSION OF MR. H. W. G. HALBAUM'S PAPER ON "CAST-IRON TUBBING: WHAT IS ITS RATIONAL FORMULA?"†

Mr. H. W. G. Halbaum (Birtley) wrote that he had overlooked certain clerical errors in some of the figures contained in his paper, as under:—

Page 598, Table I., column (B), bottom line: for 2·160 read 12·160; column (C), bottom line: for 1·750 read 11·750.

Page 616, ninth line from top: for R—, etc., read

$$\frac{R}{r}=\sqrt{\frac{f}{p}-0{\cdot}5}\pm m.$$

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* *Trans. Inst. M. E.*, 1906, vol. xxxii., page 215.

† *Ibid.*, 1907, vol. xxxiii., page 567.

MEMOIR OF SIR LOWTHIAN BELL, BART.

Sir Lowthian Bell, Bart., who was born in Newcastle-upon-Tyne in 1816, was a son of Mr. Thomas Bell, a member of the wellknown firm of Messrs. Losh, Wilson and Bell, whose ironworks at Walker, near Newcastle-upon-Tyne, were then among the largest of the kind in the country; his mother being a daughter of Mr. Isaac Lowthian, of Newbiggin, near Carlisle.

Sir Lowthian Bell received his early education at Dr. Bruce's academy in his native city, and afterwards became a student at Edinburgh University, concluding his studies at the University of the Sorbonne in Paris.

At the time when his education was considered complete, the Walker Ironworks were in the full tide of prosperity, and Sir Lowthian was appointed to the responsible position of manager. In 1850, he, together with the late Mr. Hugh Lee Pattinson and Mr. R. B. Bowman, established large chemical works at Washington, the late Mr. R. S. Newall afterwards becoming a member of the firm. In 1872, Sir Lowthian severed his connection with the Washington Chemical Works, and devoted all his time and attention to the great works which he and his brothers had founded on the banks of the Tees, and with which his name will ever be honourably associated. Mr. Vaughan, who made the discovery of the Cleveland ironstone-beds, which laid the foundation of the great iron-trade now established in the Cleveland district, had been associated with Sir Lowthian Bell at the ironworks of Messrs. Losh, Wilson and Bell, but now severed his connection with the firm, shortly before 1850, and commenced for himself near the Tees. His discovery rapidly attracted to the district some of the most energetic men which this country has produced, Sir Lowthian Bell, and his brothers Thomas and John, being among the early pioneers in the Cleveland iron-trade. In 1852, they secured about 30 acres of land at Port Clarence, on the north side of the Tees, opposite Middlesbrough, and there established the Clarence Ironworks; and from that time the wellknown firm of Messrs. Bell Brothers has held a high and honourable position in connection with the iron-trade of this country. The original site of 30 acres has been added to, and now the company owns a site of about 200 acres in extent. Ironstone-mines were opened by the firm

near Saltburn-by-the-Sea, Normanby, and Skelton-in-Cleveland, and coal-royalties in Durham were secured and worked by them, and for many years past the company has given employment to about 6,000 workmen. Every improvement in the mode of production of iron was adopted by the firm, the result being that the Clarence works have been regarded among iron-manufacturers as models of perfection. The small blast-furnaces originally erected were replaced by large structures, built on the most improved principles, and the firm was the first in Cleveland to adopt the plan of utilizing the waste-gases which escaped from the furnaces.

The great difficulty in the smelting of Cleveland ores in regard to steel is the high percentage of phosphorus (1·8 to 2·0 per cent.) contained in the cast-iron which they yield; yet Middlesbrough, largely as the results of experiments carried on under Sir Lowthian's directions, at a cost, it is said, of between £40,000 and £50,000, produces steel-rails in which the percentage is reduced to 0·07 or less. Many thousand tons of such basic-steel rails have been laid on the North-eastern Railway, and the careful records kept of their behaviour convinced Sir Lowthian that neither in loss of weight by wear nor in the number of breakages did they give any grounds for complaint In connection with rails, it is interesting to note, as an illustration of the advances made during his exceptionally long and active life, that he remembered wooden rails in use on the tramroads by which coal was brought down to the river Tees.

To Messrs. Bell Brothers, Middlesbrough is also indebted for the development of the salt industry. In 1862, Messrs. Bolckow and Vaughan, when boring for water for their works on the south side of the Tees, proved a bed of salt at a depth of 1,313 feet; but apparently no use was then made of so important a discovery. Ten years later, Messrs. Bell Brothers had a boring made at Port Clarence, on the north side of the Tees, and, at a depth of 1,127 feet, found a stratum of salt, which is about 100 feet thick; and in the year 1882 commenced working this valuable bed of rock-salt. In 1888, they disposed of their salt-works to the Salt Union, Limited; and in the year 1884, erected a soda-works, where alkali containing 58 per cent. of causticity was manufactured by the ammonia process, invented by Mr. Schlœsing, the eminent French chemist.

Sir Lowthian was ever ready to give a trial to any suggested improvement in connection with the manufacture of iron; and the high reputation which he deservedly held as a chemist and iron-manufacturer, caused him to be regarded as one of the greatest authorities on the subject in the North of England. His reputation as an authority on all matters connected with mineralogy and metallurgy was not confined to this country, for he was equally looked up to in the United States of America and in many European countries. At the meeting of the British Association for the Advancement of Science, held in Newcastle-upon-Tyne in 1863, he read a paper "On the Manufacture of Iron in connexion with the Northumberland and Durham Coal-field;"* and at a meeting of the Iron and Steel Institute, held at Middlesbrough in 1871, he read a most valuable paper on the "Chemical Phenomena of Iron Smelting."† The latter paper was frequently added to, as its author made more experiments; until it at last appeared in the form of a bulky volume, which came to be regarded as a standard authority in the iron-trade, not only in this country, but also in Europe and America. The book has been translated into the German, French, and Swedish languages. Another book to which Sir Lowthian Bell made valuable contributions is *The Industrial Resources of the Tyne, Wear and Tees* (1863).

In 1854, Sir Lowthian became a member of The North of England Institute of Mining and Mechanical Engineers; he was elected to the Council in 1865, in the following year became one of its Vice-Presidents, and, in 1886, was elected President. He was one of the founders of the Iron and Steel Institute, and followed Sir Henry Bessemer in the Presidential Chair in 1874. He was a Fellow of the Royal Society and of the Chemical Society of London, a member of the Society of Arts and of the British Association for the Advancement of Science, and a Member of The Institution of Civil Engineers. He was a member of the Institution of Mechanical Engineers, and was elected President of that Institution in 1884; and had also been a member and President of the Society of Chemical Industry.

* *Report of the Thirty-third Meeting of the British Association for the Advancement of Science, held at Newcastle-upon-Tyne*, 1863, page 730.

† *The Journal of the Iron and Steel Institute*, 1871, vol. i., pages 85 and 277; vol. ii., pages 67 and 277; and 1872, vol. i., page 1.

For his scientific work he was honoured by many of the learned societies of Europe and America. When the Bessemer Gold Medal was instituted by the Iron and Steel Institute in 1874, Sir Lowthian was the recipient. On the presentation to the Royal Society of his paper "On some supposed changes Basaltic Veins have suffered during their passage through and contact with Stratified Rocks, and on the manner in which these Rocks have been affected by the heated Basaltic,"* he was elected a Fellow on May 27th, 1875. In 1885, on the advice of Mr. Gladstone, a baronetcy was conferred upon him in recognition of his great services to the State. From The Institution of Civil Engineers he received the George Stephenson Medal in 1900, and in 1891 the Howard Quinquennial Prize, which is awarded periodically to the author of a treatise on iron. In 1895, he received at the hands of the King (then Prince of Wales) the Albert Medal of the Society of Arts, in recognition of the services rendered to arts, manufactures, and commerce by his metallurgical researches. From the French Government he received the decoration of the Legion of Honour. He was a D.C.L. of Durham University, an LL.D. of the Universities of Edinburgh and Dublin, and a D.Sc. of Leeds University.

With his chief interest centred directly on the manufacture of iron, and as one of the original founders of the Iron and Steel Institute, it was only natural that after its birth he should favour it with the bulk of his writings; yet, in the early days of The North of England Institute of Mining and Mechanical Engineers, he devoted considerable time to its welfare and success, and took an active part in the discussion of all papers read bearing upon any subject upon which he could throw enlightment.

An explosion took place at Hetton Colliery on December 20th, 1860, in the boiler-flues of one of the engines near the bottom of the downcast shaft. The force of the explosion blew down an air-crossing over the main wagonway, and then penetrated inbye, with the most serious results, 22 persons, 9 horses, and 56 ponies being killed, as well as considerable damage being done to the pits. Sir Lowthian, along with Dr. Richardson, two of the leading scientific and manufacturing chemists of the district, were called in, with a view of ascertaining if they could by their chemical knowledge account satisfactorily for so extra-

* *Proceedings of the Royal Society of London*, 1875, vol. xxiii., page 543.

ordinary an explosion, and the conclusion arrived at was that the disaster was due to the presence of underground boilers, the accident being caused entirely by the damping of the fire with a large quantity of coal; and the dampers having been too closely put down, the distillation of gas from these coals oozing through underneath the dampers filled the flues with explosive gas because too little air was allowed to pass to sweep it away as it was generated.

In 1861, he was appointed, together with the late Mr. Nicholas Wood and the late Mr. John Tom Woodhouse, by the Council of The North of England Institute of Mining and Mechanical Engineers, to give evidence before the Commission appointed by the Home Office to enquire into the constitution and management of the University of Durham, with a view to inducing the authorities to incorporate with the University a practical Mining College; and in 1868 the Council again appointed him with the late Sir George Elliot (first baronet) and the late Mr. William Cochrane, to give evidence before the Parliamentary committee then sitting to consider the advisability and the best means of initiating and extending technical education throughout the district.

On the founding of the Durham College of Science (now Armstrong College) in Newcastle-upon-Tyne in the year 1871, he was appointed a Governor, and continued to serve on that body throughout his long life. From the first he took a very great interest in technical and scientific education, and remained to the last a generous friend of the College, one of his latest benefactions being a donation of £4,500 to defray the entire cost of the building of the main tower, which bears his name. His son, Sir Hugh Bell, Bart., presented to the library of the College a large collection of valuable books from his father's library.

He was a director of the North-eastern Railway Company from the year 1865 until his death, and for many years was vice-chairman, and chairman of the locomotive committee.

Among other labours, he served on the Royal Commission on the Depression of Trade, and formed one of the Commission which in 1866 proceeded to Vienna to negotiate free trade with Austria-Hungary. He also gave evidence before the Parliamentary committee on the coal question in 1873. He acted as judge at the Philadelphia Exhibition of 1876, and as a juror at the Paris Exhibitions of 1878 and 1889. He served as a

member of the Executive Council of the International Inventions Exhibition, London, in 1885, and at several other great British and foreign exhibitions. He was a member of the Council of the Imperial Institute (acting as Vice-Chairman of the Organizing Committee of that body), the appointment having been made by His Majesty the King (then Prince of Wales) in 1888.

He was a justice of peace for the county of Durham, and deputy-lieutenant and high-sheriff in 1884. He was also a justice of the peace for the North Riding of Yorkshire, and for the city of Newcastle-upon-Tyne.

As a large employer of labour, Sir Lowthian Bell was a keen observer of, and took a warm interest in, everything relating to the welfare of his workmen. At an early stage of the general strike of miners in the County of Durham in 1879, as head of the firm of Messrs. Bell Brothers he announced his willingness to accept arbitration in the difficulty with their workpeople, this proposal being readily accepted. The men returned to work, and shortly afterwards mining operations throughout the entire county were resumed.

Sir Lowthian always took a deep interest in the prosperity of his native city. He entered the Town Council in 1850, was elected to the ancient and honourable office of sheriff in 1851; and on November 9th, 1854, he was elected mayor. The chief events of his mayoralty were the laying of the foundation-stone of the Town Hall buildings, and the opening of a new wing at the Royal Infirmary. In October, 1859, Alderman Joseph Lamb died, and Sir Lowthian was then unanimously elected an alderman, and retained his seat on the Council until November 9th, 1880.

The invitation to the British Association for the Advancement of Science to hold its meeting in Newcastle-upon-Tyne in 1863 having been accepted, it was necessary that the Council should elect to the post of chief magistrate a gentleman who, by his ability and learning, was qualified to welcome the members of so learned an Association to the metropolis of the north, and the choice of the Council fell a second time upon Sir Lowthian. Not only did Sir Lowthian worthily maintain the reputation of the town for hospitality, but he also, as before mentioned, read a valuable paper to the members of the Association.

Throughout his life Sir Lowthian took a fair share of interest in politics, supporting the moderate Liberals until the

rupture in the party on the Home Rule question, when he joined the Unionists. His connection with Tyneside and the county of Durham, in the industrial prosperity of which he was so deeply concerned, led to his being selected in 1868 by the Liberal party as a fellow-candidate with Sir Hedworth Williamson for North Durham, in the place of Mr. Shafto, one of the retiring members. The Conservatives were represented by the late Sir George Elliot (first baronet). A long and well-fought contest was brought to a termination in November, 1868, the defeated candidate being Sir Lowthian. The next general election took place in February, 1874, and Sir H. Williamson, not being willing to fight another contested election, retired, and the Liberal party brought forward Sir Lowthian and the late Sir C. M. Palmer in opposition to Sir George Elliot and Mr. R. L. Pemberton. The polling resulted in the defeat of the Conservatives. For only a brief time did Sir Lowthian Bell and Sir C. M. Palmer enjoy their victory, as a petition was lodged by the Conservative candidates, and resulted in their being unseated on the ground of general intimidation by agents. Sir Lowthian contested the Hartlepools in 1875, and was returned at the head of the poll. For five years Sir Lowthian enjoyed the honour of a seat in the House of Commons, and rendered great service in committees, his great knowledge of the commercial industries of the country being invaluable. He was ousted from his seat at the general election in April, 1880.

Sir Lowthian Bell, in 1842, married the second daughter of the late Mr. Hugh Lee Pattinson, and had a family of two sons and three daughters. For many years he resided in Newcastle-upon-Tyne, removing to Washington Hall on the establishment of the chemical works at Washington. On the severance of his connection with the Washington Chemical Company, he took up his residence at Rounton Grange, near Northallerton.

He was one of the founders of The Institution of Mining Engineers, and was elected President at the annual general meeting held at Birmingham on September 14th, 1904, but died at his residence, Rounton Grange, Northallerton, on December 21st of the same year, in his eighty-ninth year, and was buried at Rounton two days later in the presence of the members of his family and a large gathering, comprising representatives of all classes. At a memorial service held simultaneously at Middlesbrough, the Dean of Durham delivered an address in which he

pointed out that Sir Lowthian's life had been one of the strenuous exertion of great powers ever grappling and successfully combating with the difficult problems which have revolutionized the engineering world during his long life, giving life-long denial to the statement that Englishmen can always "muddle through," for he based all his action and success on clearly-ascertained knowledge.

Among the many expressions of sympathy conveyed to the family of the late Sir Lowthian Bell, was one from the King, who was pleased to say that he had a great respect for Sir Lowthian, and always looked upon him as a very distinguished man. The Council of The Institution of Mining Engineers passed the following resolution:—

> The Council have received with the deepest regret intimation of the death of their esteemed President and colleague, Sir Lowthian Bell, Bart., one of the founders of the Institution, who presided at the initial meeting held in London on June 6th, 1888, and they have conveyed to Sir Hugh Bell, Bart., and the family of Sir Lowthian Bell an expression of sincere sympathy with them in their bereavement. It is impossible to estimate the value of the services that Sir Lowthian Bell rendered to The Institution of Mining Engineers in promoting its objects, and in devoting his time and energies to the advancement of the Institution.

He is succeeded in the title by his eldest son, Hugh, who also takes his late father's position as managing partner of the firm of Messrs. Bell Brothers, Limited.

APPENDICES.

I.—NOTES OF PAPERS ON THE WORKING OF MINES, METALLURGY, ETC., FROM THE TRANSACTIONS OF COLONIAL AND FOREIGN SOCIETIES AND COLONIAL AND FOREIGN PUBLICATIONS.

BROWN-COAL DEPOSITS OF UPPER LAUSITZ, SILESIA.

Die Braunkohlenformation des Hügellandes der preussischen Oberlausitz. By KURT PRIEMEL. *Zeitschrift für das Berg-, Hütten- und Salinen-wesen im preussischen Staate*, 1907, *vol. lv., Abhandlungen, pages* 1-72, *with* 13 *figures in the text and* 6 *plates.*

The brown-coal deposits of this district constitute the western portion of the so-called Sub-Sudetic brown-coal formation, that is, the lignite-bearing Tertiaries which are banked up on the northern margin of the Sudetic range. To the south and to the west of them lie near at hand the brown-coal deposits of the neighbouring kingdom of Saxony; and, through their connexion with the brown coals of Brandenburg and Posen, they may be regarded as a part of the great series of such deposits which extends over East and West Prussia, Pomerania, Mecklenburg, Silesia, etc., known generally as "the North-east German brown-coal formation." According to Prof. H. Credner's view, this is of Miocene age, while he assigns to the Lower Oligocene the so-called Sub-Hercynic brown-coal series (Harz region, Halle, Leipzig, etc.).

The hilly portion or highland country of the Upper Lausitz, with which Dr. Priemel's memoir more especially deals, is built up of flat ridges of ancient granites, gneisses and slates, traversed by eruptive basalts which seem occasionally to follow a certain alignment. In the hollows among these older hills lie considerable masses of the Tertiary formation (the brown coal-bearing beds included) capped by Quaternary deposits, in their turn forming flat-topped hills, which lend additional variety to the landscape, rising to altitudes of 1,000 feet or more above sea-level. The Neisse, the principal river of Upper Lausitz, cuts through the granite at Görlitz in a deep gorge of erosion; but, as it flows northward, its meanders gradually become more frequent, while the hills become fewer and lower, merging finally into the barren sandy heath-country characteristic of the North German plain.

Although it is possible to distinguish several brown-coal basins wherein the coal-bearing Tertiary deposits have attained a considerable thickness, it would be a mistake to speak of "Tertiary basins," as it is the coal-seams alone that are discontinuous or cut off one from the other, while the sands and clays of the formation almost invariably spread from one basin to the next, linking the whole series together.

A description is given of the rocks which underlie the brown-coal formation: namely, the granites and gneisses; the Silurian grauwackés and quartz-schists; the Permian limestones and quartzless porphyries; the red sandstones, etc., of the Trias; the Upper Cretaceous sandstones and mottled clays. As to the eruptive columnar basalts, there is no doubt that, with some rare exceptions, they also are older than the brown-coal formation. There is,

however, proof that eruptions were still continuing even during the deposition of that formation.

The author then proceeds to describe in succession (1) the Görlitz-Ostritz brown-coal basin; (2) the finds of coal west and north-west of Görlitz, which do not seem to be of much importance; (3) the Hermsdorf-Schönbrunn coal-belt; (4) the Troitschendorf coal-basin; (5) the brown-coal deposits in the neighbourhood of Lauban and Lichtenau-Geibsdorf; (6) those of the Marklissa district (unimportant); (7) the brown-coals of the western extension of the Löwenberg basin; and (8) those of the Muskau district. He adds to these, for the sake of comparison, a description of the Zittau basin, across the border in Saxony. Details are given of a great number of bore-holes, and the fifth chapter of the memoir is devoted to a consideration of the pressures and thrusting which the Tertiaries of the region underwent during the Glacial period.

The sixth chapter is taken up by a stratigraphical summary; and in the eighth chapter the final results of the author's minute and laborious investigations are set forth, somewhat as follows: The brown-coal formation of Upper Lausitz includes on an average one to two seams, which may, however, be split by partings occasionally into four or more seams. The thickness of the seams ranges from 20 inches to 52½ feet, leaving out of account thinner and industrially unimportant seams. Given an average thickness of Tertiary deposits, brown-coal is almost invariably found, if not always at workable depths; and at the very least such substitutes as bituminous marls or clays with vennles of coal occur. There are some cases of wash-out. The beds of the brown-coal formation, consisting as they do of clays, sands, gravels and coal-seams, are of extraordinarily variable character, and any attempt to tabulate (even locally) a normal succession of the strata within that formation is all but impracticable. On the whole, its age may be set down as Lower Miocene, and the seams appear to have originated from the drifting-together of plant-remains in lakes and flood-areas.

The Lichtenau district is a typical scene of active mining operations, the Glückauf mine there being the most important of any in Upper Lausitz. Shafts are sunk some 120 to 150 feet down to the main seam, which attains a maximum thickness of 40 feet in the middle of the basin, gradually thinning out towards the edges. The yearly output of brown-coal averages 106 million cubic feet (tonnage not stated), the number of workpeople employed in and about the mine being 400. The coal yields only 4 per cent. of ash, and its heating-power is equivalent to 2,500 calories. Two briquette-factories are attached to the mine.

The brown-coal worked in the Louisa mine at Nieder-Schönbrunn is of such ligneous character that, even when moist, it cannot be compressed into briquette-fuel. The average yearly output amounts to 688,000 bushels (tonnage not stated), the number of workpeople oscillating between 40 and 50. A pumping-installation above bank drains the mine of 220 gallons of water per minute. The main or upper seam attains a maximum thickness of 13 feet, and is separated by 4 to 5 feet of marl from the lower seam, which varies in thickness from 20 to 40 inches. The various shafts in use go down to depths of 130 and 160 feet.

In the Troitschendorf district, the Joseph Hermann mine employs 30 workpeople, and yields an annual output of some 12,000 tons. Two shafts are sunk, and the pumping-engines drain the mine of 286 gallons of water a minute. Speaking generally, the Troitschendorf seam increases in thickness eastward and south-eastward from 6½ feet to 20; the coal is tough and compact, yields 5¾ per cent. of ash, and contains no less than 53·06 per cent. of water.

In the northernmost bay of the Görlitz-Ostritz basin, the Friedrich Anna mine at Moys, where two shafts are sunk to a depth of 154 feet, produces annually 64,000 tons of coal; 30 per cent. of this, classified as dust, is used up in the briquette-factory attached to the mine. The pumping-installation below bank is capable of dealing with over 1,100 gallons of water per minute; but the average flow does not, as a matter of fact, exceed 550 gallons per minute. The mine employs 120 workpeople. The main seam averages 29½ feet in thickness, gradually decreasing to 6½ feet towards the rim of the basin, the seam then rising very steeply and suddenly nipping out.

L. L. B.

POSIDONIA BECHERI IN UPPER SILESIAN COAL-MEASURES.

Das Auftreten von Posidonia Becheri in der oberschlesischen Steinkohlenformation. *By* R. MICHAEL. *Zeitschrift der Deutschen geologischen Gesellschaft*, 1905, *vol. lvii., Protokolle, pages* 226-229.

Prof. Fritz Frech having announced that *Posidonia Becheri* has now been proved to range up into the productive Coal-measures, and that consequently the discovery of that fossil in the process of boring for coal should not discourage the prospector, the author sets himself to controvert this conclusion, and to show that it is at all events inapplicable to the Upper Silesian coal-field. There, a series of strata, 13,000 feet in thickness, intervenes between the undoubted Kulm slates containing *Posidonia Becheri* and the beds which contain *Posidonia constricta* (or *membranacea*). These are still to be regarded as two distinct species, although Prof. Frech maintains that in reality the finely-ribbed *Posidonia constricta* is specifically indistinguishable from *Posidonia Becheri*.

The true *Posidonia Becheri* is confined in Upper Silesia to the barren Lower Carboniferous, and the author warns all whom it may concern against the useless expenditure of time and money in boring for coal in areas which have been accurately mapped as Kulm. Moreover, he believes that the same statement, in regard to the restriction of the range of *Posidonia Becheri*, will be found to hold good in Westphalia also. L. L. B.

ASPHALT-DEPOSIT AT METTENHEIM, HESSE.

Ueber ein Asphalt-Vorkommen bei Mettenheim in Rheinhessen. *By* A. STEUER. *Notizblatt des Vereins für Erdkunde und der Grossherzoglichen Geologischen Landesanstalt zu Darmstadt, series* 4, 1905, *part xxvi., pages* 35-48.

The village of Mettenheim lies on the west side of the Rhine valley, about midway between Worms and Oppenheim, at the base of a vineclad elevation. This elevation represents the eastern abutment of the Tertiary deposits along the great Rhenish fault, although they are mostly concealed from view by a great mass of drift and loess. In digging for wells in the neighbourhood, bituminous limestones have been met with, of compact structure, yellow and blue coloration, and a brittle and splintery character, interbedded among blue marls like unto the *Cyrena*-marls. The author had a bore-hole put down at a favourable spot, but, owing to the inadequacy of the available apparatus, he did not reach a greater depth than 115 feet. However, he ascertained that the bituminous limestones, struck only a few feet below the surface, are equivalents of the *Corbicula*-beds (Lower Miocene). The asphalt actually crops out in the form of a layer, 4 inches thick, in the northern bank of a hollow lane near by, and in the lane itself. Down to a depth of 65 feet or so, the asphalt recurs in the form of bands several inches thick, among the marls as well as

in the limestones; below that depth no more of it is found. Three specimens from various depths have been analysed and compared with Trinidad asphalt. They seem to be of generally higher specific gravity than the Trinidad mineral, and while that only melts at 275° Fahr. (135° Cent.) they melt at 212° Fahr. In chemical composition they bear fairly close comparison with the Trinidad asphalt, the proportion of carbon ranging roughly from 50 to 54, of sulphur from 6 to 6½, of mineral impurities from 17½ to 25½. All four asphalts were alike in regard to their relative solubility and insolubility in different liquids, such as alcohol, benzol, turpentine, etc.

The greatest enrichment of the asphalt-deposit is not so much in the limestones as in the marls, especially between the depths of 53 and 60 feet. A premature announcement in the newspapers of the results of the bore-hole caused the descent of an avalanche of enquiries upon the local municipal authorities, some speculators wishing to bore eventually for petroleum (which in the Mettenheim district would be a quite hopeless undertaking, judging from the available geological data).

It does not seem very likely that even the asphalt will repay working, on anything like a commercial scale. At all events, an old mining concession, granted under the laws promulgated during the Napoleonic régime, and covering the entire commune of Mettenheim, has still legal force, and it includes the asphalt-deposit. L. L. B.

KAOLIN-DEPOSITS OF HALLE-AN-DER-SAALE, SAXONY.

Die Entstehung der Kaolinerden der Gegend von Halle a. S. By Ewald Wüst. *Zeitschrift für praktische Geologie*, 1907, *vol. xv., pages* 19-23, *with* 7 *figures in the text.*

The kaolin-earths of the Halle district are, for the most part, derived from quartz-porphyries; but how they are so derived has long been a matter of controversy. According to one hypothesis, the quartz-porphyries (mantled over though they were by Tertiary deposits, drift, and alluvia in succession) were and are being decomposed by atmospheric agencies; the process, which began as far back as the Upper Oligocene time, has continued down to our own day, and that very mantle of later deposits has prevented the products of decomposition of the porphyries from being swept away to other localities. According to another hypothesis, the kaolinization of the quartz-porphyries is the outcome of post-volcanic pneumatolytic and hydrothermal phenomena immediately connected with the eruption of the porphyries, and consequently dating back to the Lower Rothliegende period. The author's own researches have led him to propound a theory essentially different from either of those just outlined. He attaches some importance to the fact that there is a certain amount of regularity about the distribution of the Halle kaolin-deposits; in every case they are associated with the older Tertiary land-surface, upon which the continental sediments of the Lower Oligocene brown-coal formation were laid down. Wherever the quartz-porphyries immediately underlie these Lower Oligocene deposits they are kaolinized, and the author regards the Halle kaolin-earths, as a whole, as forming a portion of an extensive crust of weathering, in part broken and disjointed by later denudation. But many other pre-Tertiary formations, besides the porphyries, constituted the above mentioned ancient land-surface; and, wherever they occur in contact with the Lower Oligocene plane of deposition, they exhibit signs of intense chemical decomposition:—thus the Lower and Upper Rothliegende arkoses, the Upper Rothliegende porphyry-breccias and porphyry-conglomerates are kaolinized, the red sandstones both of the Rothliegende and the Bunter are bleached, as also the

red marls of the same formations, the Muschelkalk limestones are in part crumbled away to calcareous sands, and so forth.

The crust of weathering below the older Tertiary land-surface is here defined as belonging to the group of the grey earths, which are essentially characterized by kaolinization of the felspars, bleaching of the ferruginous constituents, and in damp climates are the outcome of the action of humic acid on the components of the surface-rocks. This crust was already in existence when the Lower Oligocene brown-coal deposition was beginning; and, no doubt, under conditions which were so favourable to the activity of humic acid as those of the brown-coal epoch were, the crust must have further increased in thickness. The point which the author perhaps most of all emphasizes, in sketching the origin of the Halle kaolin-earths, is the influence of humic acid; but he expressly disclaims any desire to put this forward as the principal factor in the genesis of all kaolin-earths. He agrees nevertheless with Dr. E. Ramann that, probably, most of the kaolin-deposits of Central Europe were formed in Tertiary times by humic-acid weathering. The practical interest of the paper, if the author's views prove unassailable, lies therein that kaolin-earth deposits may be looked for wherever porphyries form the bed-rock of the ancient Tertiary land-surface; now, by piecing together evidence from various sources, it will prove quite possible to map out this ancient surface, and this is an undertaking to which the author will shortly address himself. L. L. B.

NICKELIFEROUS MAGNETIC PYRITES OF THE BLACK FOREST, BADEN.

Die Nickelmagnetkieslagerstätten im Bezirk St. Blasien im südlichen Schwarzwald. By E. Weinschenk. *Zeitschrift für praktische Geologie*, 1907, *vol. xv., pages* 73-86 *and* 2 *plates.*

In the autumn of 1906, the author made a detailed study of the deposits of nickeliferous magnetic pyrites, situated in the district of St. Blasius, in the southern portion of the Black Forest, being partly moved thereto by the fact that, although repeatedly mentioned by many writers, these deposits had not so far been made the object of really careful investigations on the spot.

He begins with suggesting the erasure, from the list of acknowledged mineral species, of horbachite (so-called by Prof. Knop from the farmstead of Horbach, near Wittenschwand) declaring it to be synonymous with true nickeliferous magnetic pyrites. At the same time, he admits that chemical analyses of specimens of the ore, taken from the Horbach mine, show it to be a fairly constant mixture of iron and sulphide of nickel, corresponding either to the formula Fe_3NiS or to the formula Fe_4NiS; and that consequently the name "horbachite" may ultimately hold good. This ore is constantly associated with varying quantities of iron-pyrites and chalcopyrite, the former of which plays a very subordinate part in the opencast workings at Horbach (and would appear to be of small industrial value, as it contains at most a minute proportion of cobalt). The chalcopyrite, on the other hand, assumes occasionally some importance; and the general average ratio of nickel to copper in the Horbach ores ranges between 2:1 and 3:1. The infinitesimal proportion of platinum which usually characterizes the metalliferous ores in other districts of the Black Forest is here conspicuous by its absence.

Stress is laid on the general resemblance between the Scandinavian and Canadian nickel-ore deposits and those here described, despite admittedly marked differences in individual details. All nickeliferous magneto-pyritic ores, properly so called, lie within the direct sphere of influence of granitic

in the limestones; below that depth no more of it is found. Three specimens from various depths have been analysed and compared with Trinidad asphalt. They seem to be of generally higher specific gravity than the Trinidad mineral, and while that only melts at 275° Fahr. (135° Cent.) they melt at 212° Fahr. In chemical composition they bear fairly close comparison with the Trinidad asphalt, the proportion of carbon ranging roughly from 50 to 54, of sulphur from 6 to 6½, of mineral impurities from 17½ to 25½. All four asphalts were alike in regard to their relative solubility and insolubility in different liquids, such as alcohol, benzol, turpentine, etc.

The greatest enrichment of the asphalt-deposit is not so much in the limestones as in the marls, especially between the depths of 53 and 60 feet. A premature announcement in the newspapers of the results of the bore-hole caused the descent of an avalanche of enquiries upon the local municipal authorities, some speculators wishing to bore eventually for petroleum (which in the Mettenheim district would be a quite hopeless undertaking, judging from the available geological data).

It does not seem very likely that even the asphalt will repay working, on anything like a commercial scale. At all events, an old mining concession, granted under the laws promulgated during the Napoleonic régime, and covering the entire commune of Mettenheim, has still legal force, and it includes the asphalt-deposit. L. L. B.

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masses, occurring perhaps especially along the contact-zone of a granite and a more basic eruptive; but they are not limited to one or to the other of these rocks, although as a rule they are incomparably more fully developed in the basic eruptive. In its fresh condition identified as an olivineless, frequently quartziferous norite (but metamorphosed successively into olivine-gabbro, picrite, and even hornblende or bronzite-peridotite) this forms the typical matrix of the nickel-ores in Norway as in Canada, in Piedmont as in the Southern Black Forest. It would seem evident that the granite is the younger rock, which welled up after the solidification of the original ore-carrier, and often enwrapped masses of the more basic rock.

Once the drift-deposits of the Rhine-valley are left behind, the country thence as far as St. Blasius is seen to consist of a complex of granites and gneisses among which is repeatedly intercalated a variety of so-called "crystalline schists," the literature of the subject according special mention to serpentine; among these are intruded a great number of eruptives, in the form of dykes and sills, the quartz-porphyries between St. Blasius and Höhenschwand furnishing conspicuous examples thereof. A few patches of Bunter Sandstone and of drift overlie in places the crystalline rocks. The narrow valleys and gorges afford innumerable fine exposures, and quarrying operations are active, the rocks being of use, some as building-stones and others for road-metal. The most important metalliferous mines, for the greater part worked opencast, are that of Horbach (already mentioned) and that in the Scheuerloch at Todtmoos.

The granites frequently tend to become markedly porphyritic, while on the other hand they pass by every conceivable gradation into the gneisses. The dyke-rocks are described in some detail, and the author then proceeds to show that the so-called "serpentinized gneisses" (regarded by some observers as good indicators of the nickel-ore), never were gneisses, nor are they by any means trustworthy indicators. Despite the extensive exposures afforded by the opencast workings of Horbach and Todtmoos, geological investigation is considerably hampered by the fissured and crushed condition of the rocks; moreover, the weathering of the pyrites has set up much superficial decomposition, and efflorescences of pale-green salts of nickel and bluish-green salts of copper everywhere help to mask the original appearance of the rock. Nevertheless, it is ascertainable that the richest ore (consisting mainly of sulphides) is concentrated in a compact dark rock, seamed in places by veins of white to pinkish aplite which broaden out into almost horizontal sheets. At Todtmoos, where the ores assume the form of lodes, the despised iron-pyrites occurs in considerable quantity; while at Horbach such ore as occurs in masses consists chiefly of feebly-lustrous nickeliferous magnetic pyrites, but the more frequent occurrence there is in the form of an abundant impregnation of the rock, the chief associates of the nickel-ore being magnetic pyrites, chalcopyrite, and but little ordinary pyrites. Not much of all this is very visible in the hand-specimens, but their high specific gravity, the results of the chemical analyses, and finally microscopic examination, confirm the presence of far greater percentages of ore than are superficially discernible.

Although both these ore-deposits (Horbach and Todtmoos) belong to zones which have undergone the most intense contact-metamorphism, it is still possible to identify the unaltered basic eruptives. Thus, the norite of Todtmoos (described in detail) agrees in every particular with the most typical norites of Sudbury. From Horbach comes a very fresh rock, but of far more basic character, being a true hornblende-gabbro, the felspar of which has been determined as labradorite. But perhaps the most noteworthy rock of all is

that which predominates in the Horbach mine: macroscopically, it appears to resemble the blue ground of the South African diamond-fields; its high specific gravity and its high percentage of nickel (4 to 5) contrast with its unpromising appearance in the hand-specimen, so far as metalliferous ores are concerned.

The question of the genesis of the ore-deposits is discussed at some length, and reasons are adduced for holding that the basic eruptive rocks were themselves originally free from nickeliferous and cupriferous pyrites; these ores were brought in after the intense metamorphism of the rocks, largely attributable to the influence of the granitic magma, had taken place. In a word, these and similar nickeliferous deposits are not the outcome of magmatic differentiation, but are properly defined as contact-deposits in the genesis of which a molten granitic-aplitic complex played a prominent part. At the same time, the deposition of nickel more especially (as contrasted with the absence of nickel in many other ore-deposits of similar origin) may be traced to electrolytic action originating in the basic eruptive rocks. L. L. B.

STANNIFEROUS DEPOSITS OF THE FICHTELGEBIRGE, BAVARIA.

Das Vorkommen von Zinnstein im Fichtelgebirge und dessen Gewinnung im Mittelalter. *By* ALBERT SCHMIDT. *Zeitschrift für das Berg-, Hütten- und Salinen-wesen im preussischen Staate*, 1906, *vol. liv., Abhandlungen, pages* 377-382, *with* 1 *figure in the text and* 1 *plate.*

In the district with which the author deals, the axis of the Thuringian Forest cuts across the axis of the Erzgebirge, and the mutual shock of these mountainous massifs has promoted by its metamorphic effects the formation of rare minerals. In the main, the Fichtelgebirge is built up of granite, and attains a maximum altitude of 3,454 feet. It was the scene in remote historical times and in the Middle Ages of an active mineral-industry, chiefly directed to the washeries for stream-tin. At one locality only was cassiterite actually mined in its quartz-matrix by means of shafts and adits, and that was in the immediate neighbourhood of Weissenstadt. The geological conditions of the occurrence of the ore are identical with those observed in other more famous tin-mining districts. Its presence is undoubtedly traceable to pneumatolytic phenomena connected with the extrusion of the granites: fluorspar, lithia-mica, tourmaline, topaz, apatite, beryl, associated in magnificent druses, and the sporadic appearance of greisen, complete a catalogue that is familiar to us from other localities. The tinstone itself occurs only at the contact with the granite, where the inevitable fissure facilitated the full development of fumarolic action. At Schönlind, near Weissenstadt, six stanniferous lodes have been identified, striking from south-south-west to north-north-east through a gneiss very similar to mica-schist, and pinching out in a hard stanniferous diorite-schist. Tin-mining was pursued here for more than three centuries from 1402 onwards, and the old adits and heapsteads were still to be seen about 20 years ago, but now all has been levelled. At the Seehaus, the highest point (3,122 feet) where human habitations exist in the Fichtelgebirge, cassiterite was at one time mined in a quartz-vein, but the workings are now overgrown with forest and whortleberry-bushes. Other abandoned workings are described, and it is evident that the lamentable Thirty Years' War wrought dire havoc among the mines of this district.

The author hints at a possibility of re-opening the Schönlind mines, the old plans of which are still available, and even the long-abandoned Seehaus workings; but he is more than doubtful as to the chance of stream-tin washeries in that district ever proving remunerative again. L. L. B.

HOLZAPPEL METALLIFEROUS BELT, HESSE-NASSAU.

Die südwestliche Fortsetzung des Holzappeler Gangzuges zwischen der Lahn und der Mósel. By G. EINECKE. *Bericht der Senckenbergischen Naturforschenden Gesellschaft in Frankfurt am Main*, 1906, *part ii., Wissenschaftliche Mittheilungen, pages* 65-103, *with* 2 *maps and* 2 *plates.*

The earlier geologists, chief among them Messrs. — Bauer and F. Wenkenbach, had classified the lead, silver, zinc, and copper-ore deposits, which are dispersed through part of Hesse-Nassau between the Rhine and the Lahn, into an eastern and western group of lodes respectively. In the former was included the Holzappel metalliferous belt, traced as far back as 1841 over a length of 30 miles or more. It was thought that the extension of this belt in a south-westerly direction must be looked for towards Wellmich, Werlau, and Peterswalde. This idea must now, however, be abandoned, and the ore-belt is shown to strike through the neighbourhood of Oberwies, Schweighausen, and Dachsenhausen, to the Rhine valley at Bornhofen, passing thence by Ehr, Liesenfeld, and Sevenich, near Corweiler, where it joins up directly with a group of lodes that extends to Zell on the Moselle. Taken as a whole, this great belt has a west-north-westerly and east-south-easterly strike, with a dip in its central portion of 40 degrees, which steepens to 60 degrees towards both extremities. The rocks in which it occurs are a mighty complex of Lower Devonian (Coblentzian) quartzites, greywackés, greywacké-slates, and shales, broken through in places by intrusive diabases, porphyries, and basalts, and at some few localities unconformably overlain by strata of later age. A network of fissures some 130 to 160 feet in breadth extends through these Devonian rocks for a distance of 41 miles, from Holzappel on the Lahn to Zell on the Moselle; the fissures are infilled with quartz and metalliferous ores, with a marked enrichment (especially of galena) in the north-eastern portion. Proceeding south-westward, however, the observer will note the diminution of galena and zinc-blende, while copper-ores increase in quantity, and there is simultaneously a proportionate increase of the quartz, occasionally to such an extent as to involve the disappearance of all metalliferous ores whatsoever. On approaching the Moselle, zinc-blende is seen to increase again in quantity. It is noted that many of the cross-faults of this fissure-system coincide in direction with the tributary valleys of the Lahn and the Moselle, while in the Rhine valley there is no sign of any faulting of the ore-belt. Parallel with the lodes and occasionally uniting with them, as at the Gute Hoffnung mine at Werlau, certain white dykes course through the rocks; while a series of white dykes of later age cut across both the older dykes and the metalliferous lodes.

Detailed descriptions are given of the main lode (average thickness 3½ feet) as it is seen to occur in the Holzappel and Leopoldine Louise mines at Dörnberg, and again in the Gute Hoffnung mine at Werlau, and the reasons for controverting the earlier views as to the correlation of the Holzappel ore-belt with Mr. Wenkenbach's eastern group are marshalled at great length.

L. L. B.

PYRITES-DEPOSITS OF THE WESTERN ERZGEBIRGE, SAXONY.

Zur Kenntniss der Kieslagerstätten zwischen Klingenthal und Graslitz im westlichen Erzgebirge. By OTTO MANN. *Abhandlungen der Naturwissenschaftlichen Gesellschaft Isis in Dresden*, 1905, *pages* 86-99.

Within recent years, mining operations, long suspended, have been restarted at the ancient copper-ore workings on the Eibenberg, between Klin-

genthal and Graslitz. The industry in that region can be traced back for at least six hundred years; the volume and number of the old mine-heaps bear witness to its former extent and activity, while considerable accumulations of slag point to the association of the metallurgist with the miner.

Those who are now conducting operations have penetrated much deeper down than the old miners, and the information thereby obtained has furnished matter for the various quickly succeeding memoirs of Messrs. C. Gäbert, R. Beck, and B. Baumgärtel. The views of these authors in regard to the origin of the deposits are discussed by Dr. Mann, who has studied the rocks both in the new deep-level workings and above bank. The ore-deposit lies at the base of the tongue of Graslitz slates (which penetrates for about 3 miles eastward into the Eibenstock massif); it does not belong to the actual contact-zone, but lies rather within the group of normal slates or Lower Phyllites. These are of a pale-green colour with a silky lustre, and contain much quartz in the form of nodules; chlorite is one of the common constituents of the rock, and a small quantity of pyrites is almost invariably present. The strike is approximately north and south, and the dip about 30 degrees westward. The particular ore-body to which the name Segen Gottes (God's blessing) has been applied, is, like the other ore-bands which have been proved hereabouts, intercalated on the whole conformably among the slates. Its lower portion consists predominantly of a succession of layers (about 20 inches thick) of ordinary pyrites and magnetic pyrites: in the richest part of the deposit the partings of slate disappear entirely, but in the poorer part the slate and the ore may be found to alternate in layers of extreme tenuity. In places, the ore assumes rather the form of lenticles and pockets, which, however, still show a general conformity with the country-rock. The occasional brecciated structure of the magnetic pyrites is not very easily accounted for; that the magnetic pyrites was deposited later than the ordinary pyrites may be inferred from the fact that broken crystals of the latter are often found enveloped by the former.

The upper portion of the Segen Gottes deposit differs from the lower, both in its mineralogical composition and in its habit or facies as a whole. While in the lower part the general conformity extends down to the minutest details, the intercalation even of infinitesimally fine ore-bands among the schists being perfectly regular, and similarly that of tenuous schist-bands among thick bands of ore, unconformity is often a marked feature of the upper part. Here the ores not infrequently occur in the form of stringers, which traverse the schists in different directions, and are plicated and contorted into an inextricable complex, although sometimes they present the appearance of being conformably intercalated among the schists. Magnetic pyrites, iron-pyrites, copper-pyrites, zinc-blende, and quartz are all jumbled together, one or other of these minerals being absent in places. The predominant ore in these stringers, however, is copper-pyrites, the one mineral of the deposit that repays working. The occurrence of magnetic pyrites in this connexion is peculiarly interesting, as it is properly not a vein-mineral, but is generally found in metamorphic deposits. The chronological sequence of the minerals here cannot be determined; indeed, it rather looks as if they were the outcome of contemporaneous or practically simultaneous deposition.

The entire deposit, from top to bottom, yields unmistakable evidence of the action of dynamic agencies, not unrelated, perhaps, to the phenomena of mountain-building. With regard to its genesis, the author enters into an elaborate discussion of the theories generally held as to the formation and alteration of pyrites-deposits. Geologists are generally averse to concede

the possibility of a sedimentary origin for such deposits, but he points out that data which tell in favour of this hypothesis are available; and he draws attention to the part played in the deposition of pyrites by organic matter, and even by micro-organisms. In conclusion, he assumes that the lower portion of the deposit described by him is of sedimentary origin, and that the upper portion is of epigenetic origin; and that probably both regional metamorphism and contact-metamorphism are the factors responsible for the presence of magnetic pyrites. The stringers represent the results of the leaching-out of the original deposit, and there has been a selective enrichment of the copper-ore in them, owing perhaps to the "smelting" effect of the intrusive granite.

Dr. Baumgärtel publishes some criticisms of this paper in the pages immediately following it, but they do not appear to affect seriously the main facts and conclusions cited in the foregoing abstract. L. L. B.

TUNGSTEN-ORE DEPOSITS IN SAXONY.

Über ein kürzlich aufgeschlossenes Wolframerzgangfeld und einige andere neue Aufschlüsse in sächsischen Wolframerzgruben. By R. Beck. *Zeitschrift für praktische Geologie*, 1907, *vol. xv., pages* 37-45, *with* 9 *figures in the text.*

Despite the active demand which has grown up of late years for these ores, it was not until the summer of 1906 that exploration-work was seriously inaugurated in the neighbourhood of Tirpersdorf. Yet, as long ago as 1890, the officers of the Saxon Geological Survey mapped the deposits and described them in detail, the first discovery having been made in 1889 by Dr. M. Schröder, an investigator well known for his special acquaintance with the granite-massifs of the Western Erzgebirge and the Voigtland and their contact-aureoles. The metalliferous lodes in question occur in the immediate vicinity of Tirpersdorf, near Ölsnitz in the Voigtland; and their outcrops fall mostly within the outer, but partly within the inner, contact-aureole of the Bergen and Lauterbach granite-massif, which starts at the Hohe Reuth, somewhere about a mile and a quarter north-north-east of Tirpersdorf. Cambrian slates, with sills of highly amphibolized diabase, abut here against the granite, the metamorphic effect of which upon the slates is to convert them into andalusite-mica rocks, cordierite-bearing cherts, and various forms of schist, etc. Wolframite, a little molybdenite, and a pearly-grey mica occur, in association with druses and long acicular crystals of tourmaline, impregnating veins of a greasy white quartz which traverse the tourmalinized schists north, east, and south of Tirpersdorf. The wolframite, in view of the high percentage of iron and the small percentage of manganese that it contains, must be classed among the tungstates of iron: it is found in broad, tabular, imperfect crystals measuring up to 4 inches in thickness, or in compact masses. Occasionally the wolframite is seen to be in process of decomposition into brown iron-ore, in which case films and aggregates of yellowish wolfram-ochre are observed to clothe the walls of neighbouring fissures. Tourmalinization of the schists, the final stage of the contact-metamorphism, is seen to have proceeded from the lodes, as well as probably from the granite itself.

When the author visited the Gertrud mine in November, 1906, he found that three parallel lodes had been opened up, and two more (which have been since then explored) probably belong to the same group. What is provisionally termed the "main lode" strikes north 5 to 10 degrees west, dips east-north-eastward at 35 to 40 degrees, and averages 13 inches in thickness. About 30 or 33 feet below this is another lode with the same dip, and measuring some 10 inches in thickness; the remaining parallel lodes lie a little farther

away to the eastward. All the outcrops occur in the left flank of a lateral valley of the Elster river-basin, and will be easily worked by means of an adit; while an abandoned mill at the foot of the slope will be the natural scene of operations for the treatment of the ores. A mass of rock-débris from 3¼ to 5 feet thick masks the actual outcrops in every case.

With this occurrence the author contrasts the mineralogical associations of the cupriferous mines of Sadisdorf, near Altenberg, where no tourmaline is found, while on the other hand wolframite appears in company with lithia-mica, fluorspar, and apatite. Even the Sadisdorf mines are only just beginning to take rank as tungsten-producers, yielding in 1905 rather over a ton and a quarter of wolframite and 10½ tons of molybdenite. All other tungsten-ore occurrences in Saxony are or have been worked in conjunction with cassiterite-deposits, and so cannot be compared in any way with the Tirpersdorf ores, which, taking everything into consideration, constitute a so far unique type of lode, with perhaps the single exception of the Germania I. lode at Deertrail (Washington), U.S.A. The author has received and examined specimens from Deertrail, which he cannot differentiate from the Tirpersdorf mineral.

Turning then to the wolfram-tinstone lodes of Zinnwald, which averaged an annual output of 37 tons of tungsten-ore during the decade and a half from 1890 to 1905, the author states that a new mine was recently opened up close to the Bohemian frontier, and in 1905 was already yielding over 12 tons of wolframite. This mine is a delight to geologists, because it furnishes capital sections of the contact-zone between the Zinnwald granite and the Teplitz quartz-porphyry which envelops that rock on all sides. Of these a detailed description is given, noting by the way that the Hansa lode, the most productive as yet struck in the mine, is about 18 inches thick and is accompanied by a parallel stringer of mediocre or little importance. Although the dip seems to steepen greatly when the lode leaves the granite and cuts through the quartz-porphyry, the lode actually thickens in places in the latter rock, attaining a maximum therein of 3¼ feet—as far as it has been yet followed. The Wilhelm lode, on the other hand, higher up the watershed, shows at first no essential change in thickness or mineralogical composition, but gradually thins away and becomes impoverished in the quartz-porphyry, until (at a distance of 65 feet from the granite-boundary) it has dwindled to 3 inches in thickness and no longer repays working. These wolframite-lodes (so-called "seams"), clearly distinguishable from the narrow, steeply dipping stanniferous veins, are probably of slightly later origin than the latter in some cases, and practically contemporaneous in others. L. L. B.

GRAPHITE-DEPOSITS IN THE PIEDMONTESE ALPS.

La Grafite nelle Alpi piemontesi. By VITTORIO NOVARESE. *Atti della Reale Accademia delle Scienze di Torino*, 1905, *vol. xl.*, *pages* 241-254.

The announcement of the recent discovery of graphitic lenticles in the Pietre Verdi of the Val di Lanzo has induced the author to collect together into one paper the observations on similar occurrences, recorded by his colleagues and himself in the course of the geological survey of the Piedmontese Alps.

Taking for granted that Alpine graphites are in many localities, if not in all, the outcome of the metamorphism of deposits of fossil fuel, the presence of graphite in a formation may prove to be of fundamental importance in regard to the determination of the age of the rocks, as well as a considerable factor in the solution of the stratigraphical and tectonic problems that may

arise in connexion with that determination. Recent research has demonstrated that the double-zone classification of Gastaldi, which served as a good working hypothesis in its generation, is at variance with the actual facts, being in fact too refreshingly simple to square with them. Rocks, formerly lumped together all into one system, are now recognized to belong to very different ages, despite lithological and other resemblances.

The graphite of the Ligurian division of the Alps is the result of a local metamorphism of anthracites of Carboniferous age. It may be noted, by the way, that in this area the graphite-outcrops are of small importance, in comparison with the extent and frequency of the anthracite-outcrops. The converse holds good in the Cottian Alps, to which the author now passes, omitting the Maritime Alps, where no authentically recorded occurrence of graphite is known. In the Cottian Alps, the Alpine graphites assume perhaps their greatest development, occurring at two widely separated horizons—the lower being most certainly of Carboniferous age, and the upper belonging to the Mesozoic formation of the calc-schists. The most important graphitic belt, in regard both to extent and to industrial value, lies within the Dora-Varnita gneissose ellipsoid. It was first described by the author in 1898,* and the observations made since then have, on the whole, confirmed that description. In 1902-1903, the existence of seams of anthracite was proved in the graphite-belt; but, as already hinted, it would appear that in these Cottian Alps anthracite forms the exception and graphite the rule. It has also been ascertained that the best deposits of the latter mineral occur in the immediate proximity of the dioritic masses of the lower valley of the Chisone, with which are associated spotted chiastolite-schists, etc. This leads to the inference that the action of contact-metamorphism has in this region played some part in the transformation of coal-seams into graphite, the more so that the few known outcrops of anthracite are the farthest away from the eruptive rocks.

In several localities, but more especially in the little valley of Pramollo, a phenomenon has been observed identical with that already noted in the graphite-mine of Isola Grande in the Ligurian Alps. The graphite-bed sends out ramifications and apophyses which cut clearly across the country-rock; and the graphite which forms these apophyses, etc., is very much purer than the mineral of the bed itself. This may be explained as due, either to injection, conditioned by pressure, of the most bituminous, and consequently most plastic portion of the original coal-seam, previous to the action of contact-metamorphism; or to the immediate effects of that metamorphism, in which case the graphite, as the result of the distillation of the coal-seam, might have been deposited as a sublimate in fissures and other available cavities in the country-rock. The hypothesis of Dr. Weinschenk, that certain deposits of talc are derived by pseudomorphosis from graphite, appears to the author improbable in the highest degree.

The graphite-deposits occurring among the Cottian Alps in Gastaldi's "zone of the Pietre Verdi" (mostly associated with the Mesozoic calc-schists) are of small industrial value. In the Graian and Pennine Alps, on the other hand, graphites crop out at five different horizons at least. The belt of country which the author defines as that of Sesia-Val di Lanzo consists predominantly of gneisses and mica-schists; these, contrary to the opinion generally received at one time, have nothing whatever to do with the Pietre Verdi and the Mesozoic calc-schists. The presence of intrusive rocks of later date than the great foldings is characteristic, but the age of the Sesia-Val di Lanzo belt can only be determined by approximation: it is certainly as old

* *Trans. Inst. M. E.*, 1899, vol. xvi., page 520.

as the Carboniferous, and possibly very much older. In the lower Val-di-Lanzo the plumbago-deposits belong to the type of graphitic mica-schists and graphite-schists; in Val d'Orco the deposits belong to a more unusual type: the graphite occurs in the form of nodules and flakes, dispersed amid a rock carrying big garnets in a white groundmass (or matrix) irresolvable by the microscope. It seems reasonable to assume that the mode of origin of these two different types can have hardly been the same for both.

The graphite-lenticles, etc., of the northern limb of the Valsavaranche anticline are of undoubted Carboniferous age, while graphite-deposits of equally undoubted Mesozoic age have been met with elsewhere in the Graian and Pennine Alps.

A brief description is given of occurrences of graphite-bearing rocks, both north-west and south-east of the dioritic belt of Ivrea; among them are certain graphitiferous kinzigites, in regard to which the author recalls the existence of the ancient Olivadi mine in Calabria, where kinzigites have been worked for the graphite-nodules which they contained. L. L. B.

AZURITE-DEPOSIT OF THE CASTELLO DI BONVEI, SARDINIA.

Il Giacimento di Azzurrite del Castello di Bonvei, presso Mara, con alcune Osservazioni sulla Formazione dei Carbonati di Rame naturali. By F. MILLOSEVICH. *Atti della Reale Accademia dei Lincei, series* 5, 1906, *vol. xv., Rendiconti, pages* 732-740.

The metalliferous deposits which occur among the trachytic rocks of north-western Sardinia, over an area that about covers the administrative district of Alghero, have been the object of some little prospecting-work, hitherto unattended with any very brilliant results. The scientific interest which they present is, however, considerable; and so the author seized the first opportunity that presented itself of examining the cupriferous deposit worked by the Mayor of Pozzomaggiore, at the Castello di Bonvei, in the commune of Mara, about half-way between Pozzomaggiore and Monteleone, that is, about the centre of the metalliferous area as above defined.

The hills which make up the greater part of this district consist mainly of Miocene limestones capped in places by the remnants of basaltic flows of later date. In places in the valley-bottoms erosion has laid bare the andesitic and trachytic rocks (Lamarmora's "ancient trachytes") of pre-Miocene age. On the north-eastern flank of the hill, which is crowned by the ruins of the old castle of Bonvei, several bands of azurite or chessylite, intermingled with a little malachite, are exposed in a limonitic clay, overlying a pinkish andesitic trachyte. The last-named rock is much altered, contains numerous felspathic inclusions (chiefly plagioclase) and the ferro-magnesian constituents are represented by abundant biotite; it bears no trace itself of metalliferous ores, whereas the steep grey rock above (which more nearly approaches the true trachytes, and upon which the old castle stands) is mineralized. This grey trachyte has a groundmass rich in felspar-microliths and chalcedonic spherulites, with some felspathic inclusions and large and abundant crystals of hornblende; between it and the azurite-bearing clay intervenes a great siliceous dyke, a sort of compact quartzite that seems to have invaded the trachyte.

Although the workings, so far, are of the most superficial description, a considerable quantity of azurite has already been got: the bands of the ore average 8 inches in thickness, and one of them attains a thickness of 20 inches. In the upper layers, clay predominates, and the ore occurs in isolated spheroids

of varying size, sometimes conjoined, or in masses of pisolitic appearance; lower down, where the proportion of clay is smaller, the ore is grouped together in little seams or in masses presenting a compact mammillated structure. The lowermost bands, in contact with the underlying pink andesitic trachyte, have a barytic instead of an argillaceous gangue. The malachite which is associated with the azurite was evidently deposited at the same time as the latter. Few specimens of chalcopyrite and bornite have come to light thus far, but deeper workings will most probably reveal the presence of these sulphidic ores in greater quantity, especially in the quartzose dyke above mentioned.

This Sardinian occurrence recalls the Schemnitz and Kramnitz deposits of Hungary; still more vividly, in the character of the minerals and other circumstances (geological age excepted), does it recall the deposits of Chessy and Sain-Bel near Lyons. The Bonvei ore-deposit, all things considered, is probably older than the Miocene limestones which abut against the trachytic Castle-rock.

It is well known that soluble salts of copper, originating from deep-seated sulphidic ores, can react with carbonates (generally with that of lime) to form the basic carbonates of copper. And this is unquestionably the manner in which most of such ore-deposits have been formed. But, why should malachite be of so much more frequent occurrence than azurite, even admitting that the former is a more stable mineral species than the latter? And why, as at Chessy and Castello di Bonvei, should the usual preponderance be reversed, azurite predominating so enormously over malachite in both these localities? The author set himself to answer these questions by means of experiments directed to the artificial preparation of azurite. He found that this formed at temperatures lying between 167° and 185° Fahr., by means of the reaction of cupric chloride with an excess of sodium-carbonate in the presence of carbonic-acid gas, and he concludes that this excess of carbonate and the presence of the gas are probably two of the necessary conditions for the formation of azurite in nature. The propinquity of an argillaceous stratum and the intermingling of clay with the ore in course of formation, slacken the reaction, and probably help to prevent the further evolution of azurite into malachite. L. L. B.

TUNGSTEN-ORES IN THE CAGLIARI DISTRICT, SARDINIA.

Giacimento di Minerali di Tungsteno à Genna Gurèu ai Limiti fra Nurri ed Orroli (Cagliari). *By* Domenico Lovisato. *Atti della Reale Accademia dei Lincei, series* 5, 1907, *vol. xvi., Rendiconti, pages* 632-638.

The occurrence of tungstates of iron and manganese in Sardinia was first made known in April, 1898, when the author announced the results of his examination of a few small fragments obtained from the metalliferous mine of S'Ortu Beciu. In the course of two subsequent visits to the locality, he ascertained that the amount of wolfram-ore present must be very small, as on one occasion he found none at all, and on another only a minute quantity (a very few grammes) of it. Since then tungsten-minerals have been discovered at the Su-Suergiu and Genna-Gurèu antimony-mines. At the last-named mine especially does scheelite occur in such abundance and of such excellent quality, as to induce the author to journey thither in May, 1904, and February, 1905, for the express purpose of investigating the occurrence on the spot. For many years past antimony-ores have been worked here, but no one had suspected the importance which the deposit might assume, particularly in depth, in regard to its tungsten-ores. The rocks of the immediate

vicinity are schists, in part argillaceous, in part micaceous, but rarely talcose, ridged up into a series of mammillated hillocks, the appearance of which recalls in some cases volcanic cones, seamed by innumerable veins of quartz and much disturbed by porphyroidal intrusions. In these schists (which are most probably of pre-Palæozoic age) and in the underlying rocks are found first of all the antimony-ores and then, as one goes deeper down, the tungsten-ores.

The scheelite of Genna Gurèu occurs in crystalline masses, and shows in habit much resemblance with the scheelite of Zinnwald and Schlackenwald in Bohemia. In colour it ranges between pink and white, being rarely yellowish or greyish; but in every case the streak is white. It forms in the schists veins of varying thickness, which are said to attain a maximum of 8 inches; though perhaps these veins might more correctly be described as long drawn-out lenticles. In hardness the mineral is below 5 in Mohs's scale, and its specific gravity probably lies between 5·9 and 6·1. Chemical analysis shows it to consist of 80·42 per cent. of tungstic oxide (TuO_3), 19·6 of lime, and 0·07 of iron sesquioxide (Fe_2O_3), with very slight traces of silica and magnesia. Molybdenum, present in all other scheelites hitherto known, is curiously absent from the Genna-Gurèu mineral.

On his second visit, the author paid especial attention to the inferior quality of scheelite, which occurs below the schists in a more granular and compact form, commingled with meymacite, stibnite, and other sulphides of antimony and lead, amid quartzose rock. This deeper-lying schèelite is externally decomposed into a yellowish-green, occasionally orange-brown, meymacite (its ordinary decomposition-product, so named from Meymac, in the Corrèze, France, where it was found in association with native bismuth, etc.). There is no bismuth associated with the Genna-Gurèu mineral, and the meymacite itself differs in some respects from the French variety. The author's analysis, indeed, would seem to show that, according to the degree of hydration, there are various passage-minerals between the original scheelite and the ultimate meymacite. L. L. B.

METALLIFEROUS DEPOSITS OF NORTH-EASTERN SICILY.

Die geologischen und tektonischen Verhältnisse der Erzlagerstätten Nordost-Siziliens. *By* B. Lotti. *Zeitschrift für praktische Geologie*, 1907, *vol. xv., pages* 62-66, *with a map in the text.*

The geological structure of the Peloritan mountains in the province of Messina is briefly described as follows: the lowest rocks seen consist of grey or bluish-grey mica and chlorite-schists with knots of quartz, with which are associated towards the top of the series, but in quite a subordinate fashion, sericitic gneisses. Locally, the schists are metamorphosed into biotite-hornblendites, actinolite-chloritites, epidotic and garnet-bearing hornblendites, etc. Among these schists are intercalated, at various levels, but increasingly towards the summit of the series, a few bands of white and grey crystalline limestones, passing upwards into the middle group which consists predominantly of thickly-bedded crystalline limestone. This latter, however, shrinks in places into a few thin layers or into an isolated lenticle. The uppermost group consists chiefly of coarse-grained gneiss and sericite-gneiss with intercalations of mica-schist, more especially biotite-schist, traversed over large areas by innumerable veins of pegmatite. In the lowermost schists such veins are extremely rare, and in the limestones they are, with one exception, entirely absent. The age of the formations here described is a matter for conjecture; if reliance is placed on the analogies which they offer with similar Alpine formations, they may date back to the Archæan or the Silurian, or

they may date no farther back than the Mesozoic Era. Direct evidence, such as would be furnished by a fossil flora or fauna, is not available.

Ore-deposits have been known, and in part worked, in this region since the eighteenth century; but this knowledge has been, in the main, restricted to the lower spurs of the mountains. Recently another series of ore-deposits has been discovered higher up, in the very heart of the range, although no actual mining work has been carried out on them as yet. The newly discovered ores occur all but exclusively, like the earlier-known deposits, in the lowermost schist-formation, and they may be grouped as follows: (1) bedded iron-ores (magnetites) passing into ferruginous zinc-blende; (2) reef-like or lenticular quartz-masses with chalcopyritic magnetic pyrite; (3) lead-and-zinc-bearing quartz-veins; and (4) quartz-veins with fahlores and chalcopyrite.

The principal outcrops of the first formation occur on the Tyrrhenian side of the range, on the northern flanks of Monte Maulio and Monte Maorno. With the ores are invariably associated the bands of crystalline limestone, already mentioned as being interbedded with the lower schists at various horizons. The metalliferous deposits assume the form of lenticles of varying thickness—from an inch or so to 6½ feet, consisting of compact or fine-grained magnetite, with finely-disseminated particles of zinc-blende and pyrite. The limestone at the junction is occasionally impregnated with these ores. Chemical analyses show that there is every grade of passage, from a magnetite with more than 60 per cent. of metallic iron, into a true ferruginous zinc-blende. The ore-deposits have been involved in the movements of plication of the country-rock and, like it, are greatly dislocated.

A little below the middle limestones, at about the same stratigraphical horizon as the magnetites, there occur amid the schists lenticular mases of vein-quartz with ordinary pyrite and magnetic pyrite: in the central portion of the lenticles the last-mentioned ore is usually pure and compact, but towards the periphery some chalcopyrite makes its appearance. The immediately surrounding country-rock is invariably metamorphosed into epidotic and garnet-bearing biotite-hornblendites with superficial iron-staining. It is possible that these lenticles are but the dispersed fragments of what were originally fissure-veins. Analysis of a specimen of magnetic pyrite showed it to contain 47·2 per cent. of iron; 32·5 of sulphur; 0·7 of copper; 0·2 of nickel and cobalt; and 15·1 of insoluble residue.

The lead and zinc-ores, which are the predominant feature of the earlier-known deposits, occur in the area dealt with in two great quartz-reefs, one of which crops out at the base of Monte Tossazza, near the chalets of Issala, while the other is seen in the little valley of Sterra, at the foot of the Pizzo della Croce. The Issala reef is of variable thickness, expanding in places to 30 or 40 feet. The country-rock consists of gneisses and mica-schists, which are traversed by muscovitic and chloritic granite-dykes and associated with ferruginous limestones. This reef can be followed along the outcrop for 330 yards or more: the ores, consisting of galena intermingled with black zinc-blende, take the form of venules or small aggregates disseminated in the quartz. The very thickness of the reef protected it in some respect from the shattering and dislocation which overtook deposits of lesser importance; even so, it shows at the junction with the country-rock certain irregularities that bear unmistakable witness to dynamic processes connected with orogenic phenomena. The other quartz-reef contains only galena in compact masses: so far as it has been opened up, it averages 10 feet in thickness, and seems to be very highly mineralized. It is, however, so mantled over by rock-débris and vegetation, that close study of the outcrop and a reliable estimate of the industrial value of the occurrence are at present impracticable.

A little way downhill from the Issala chalets, a small quartz-vein, with venules of fahlore and disseminated particles of chalcopyrite and black zinc-blende, is seen to traverse the lower hornblendic and garnetiferous schists. The vein is 2 feet 7½ inches thick, and is extensively mineralized; it tends rather to assume a lenticular shape, and is probably a fragment of a pre-existing vein which was shattered in the course of mountain-building processes.

That groups (3) and (4) are genetically vein-deposits appears to admit of no doubt; but, in regard to groups (1) and (2)—the magnetite and magnetic pyrite—the author tentatively suggests that the first was formed by "chemical molecular substitution of limestone-bands," and that the second represents probably the shattered remnants of fissure-veins forced into, and folded in with, the beds of country-rock. He has no hesitation in asserting the genetic relationship between the ore-deposits and the granite-intrusions, the more superficial apophyses of which are traceable in the granite-dykes that have already been mentioned. It may be noted, by the way, that pyrite is of frequent occurrence in these dykes. Reasoning by analogy with similar geological and lithological conditions in Sardinia, the author holds that the ore-deposits probably date from the period that followed on the great Hercynian plication, that is, some time between the Upper Carboniferous and the Permian. But while Sardinia thereafter remained an immovable fault-block or *horst*, unaffected down to the present time by the great orogenic movements and the consequent dislocations, both Sicily and Calabria were sorely visited by the dynamic phenomena that repeatedly resulted from the great Alpine and Apennine plications in the Tertiary Period. In Sicily, the crushing, shattering, and dislocation undergone by the granite-dykes and the ore-deposits recall vividly the similar vicissitudes to which the pre-Tertiary ore-deposits have been subjected in the Apuan Alps, where indeed the miner encounters at every step great difficulties in following up the strike of the rocks.

L. L. B.

BLENDE- AND GALENA-DEPOSITS OF TRAAG, NORWAY.

Über die Erzgänge zu Traag in Bamle, Norwegen. By J. H. L. Vogt. *Zeitschrift für praktische Geologie*, 1907, *vol. xv., pages* 210-216, *with* 5 *figures in the text.*

On the western side of the Skien fjord, in the immediate vicinity of the south-western extremity of the area geologically defined as the Christiania region, a belt of metalliferous lodes strikes sensibly parallel with the junction between the fundamental rocks and the Silurian over a length of some 15½ miles, while its breadth ranges between 3 and 3¾ miles. The district is hilly, but the maximum altitudes do not exceed 660 feet above sea-level. The fundamental rocks hereabouts consist predominantly of a somewhat compressed red granite with occasional patches of hornblendite, and, in some few localities, bands of quartzite identified as belonging to the uppermost stage (the Kragerö quartzite-stage) of the Archæan system of Southern Norway. The author's researches among these rocks were limited to the neighbourhood of Traag, where mining operations have been started, north and south of which town the ore-belt extends to beyond Vaddres and Tangvall respectively. Many of the lodes were traced uninterruptedly for 2, and some for 2½ miles: by far the larger number strike parallel one with the other, and they pitch as a rule steeply (80 to 85 degrees westward), an easterly dip being exceptional. The more important lodes average 3½ to 6½ feet in thickness, but some few attain thicknesses of 15, 20, and even 25 feet. They may be shortly defined as quartz-

breccia veins, quartz being the predominant infilling-material. Calcspar is of exceptional occurrence, and fluorspar is conspicuous by its absence. Brecciated fragments of the country-rock, often highly mylonized and chemically decomposed, occur abundantly in these lodes. The principal ores are zinc-blende containing but a small proportion of iron, and galena containing an average percentage of 0·05 of silver. In some of the lodes, a little chalcopyrite and pyrites occur, while spathose iron-ore, occasionally altered into brown hæmatite, is found in others. Mining operations were begun a few years ago, and the greatest depth from the surface so far reached ranges from 200 to 230 feet. The innumerable smaller lodes are poorly mineralized. Of later age than these quartz-breccia veins, are the diabase-dykes which coincide with them in strike and dip, and alternately course along the footwall or the hanging-wall, or along the central strip of the lodes, bifurcating sometimes within them.

It seems plain that the order of events was as follows: fissures were torn in the rocks; these fissures were afterwards infilled with quartz and metalliferous ores; at a later date the metalliferous lodes, coinciding with planes of weakness in the earth's crust, were torn open again, and diabase in the molten condition was intruded along them. At Styggedalen, the exceptional occurrence of a later, very drusy, barytes-vein alongside the metalliferous quartz-breccia vein is noted.

As the broader lodes offer less resistance to the atmospheric agents of erosion than the tough, hard, country-rock, the metalliferous outcrops generally occur along small valleys or swampy tracts, as implied in the very composition of the place-name Styggedalen (ugly dale).

The author marshals at some length the evidence for regarding the above-described lodes as fault-fissures, arising in the course of the great sagging movement which took place during Devonian time, and was perhaps continued into the Carboniferous age, in the Christiania region. This region constitutes a vast *graben* or fosse, some 143 milés long and in places 50 miles broad, within which the sunken tract of the earth's crust is broken into innumerable fault-blocks thrust one against the other. The work of denudation since these phenomena took place has been so great, that it is reckoned that the present surface at Traag lies many thousands of feet—or, say, a couple of miles below the surface as it was when the lodes were formed. It seems probable that these lodes, even now extending to a depth of 5,000 feet or so, must have originally had a depth which ran into miles. L. L. B.

GELLIVAARA AND KIIRUNAVAARA IRON-ORES, NORTHERN SWEDEN.

(1) *Die Eisenerzlagerstätten bei Kiruna.* *By* O. STUTZER. *Zeitschrift für praktische Geologie*, 1906, *vol. xiv., pages* 65-71, *with* 1 *figure in the text.*

At the end of August, 1905, the author paid a visit to the deposits of the Kiirunavaara, Luossavaara, and Tuollavaara, which, probably for brevity's sake, he describes as the deposits of Kiruna, after the settlement of that name north of the Arctic circle. The annual output of iron-ore already exceeds 1,500,000 tons, and most of the workings are opencast, affording splendid and ever-varying exposures for geological study. The Kiirunavaara is a ridge extending from north to south for about 2½ miles, and rising to an altitude of 2,460 feet above sea-level; its eastern face is abrupt, while the western slopes gently downward, and its northern end abuts on the lakelet of Luossajärvi. Across the lake, the Luossavaara (altitude 2,391 feet) is the evident

continuation of the ridge just described; mining operations have not yet been begun on this northerly extension. On the other hand, an hour's journey by road east of Kiruna, a deposit analogous to that of the Kiirunavaara is worked in the small hill known as Tuollavaara.

The crest of the Kiirunavaara and the summit of its northern extension across the lake consist of pure magnetite, with some apatite, while the flanks of both ridges and those of the small hill just mentioned are made up of porphyry. The plain from which these eminences arise is partly swamp and partly a waste of drift-gravel, but syenite has been proved on the west, and the so-called Hauki Slates with conglomerates and overlying quartzites have been proved on the east.

The author proceeds to give a brief petrographical description of the rocks, going from west to east; wherefore he begins with the augite-syenite, the finer-grained varieties of which occur at the margin of the porphyry. Prof. L. de Launay's statement that a passage is observable from the former rock into the latter is here recalled. Bore-holes having proved a definite steep eastward dip of the iron-ore (varying between 50 and 60 degrees), the western porphyry is termed the footwall-rock and the eastern the hanging-wall; the former, of a greyish-green colour, is generally more basic than the latter variety, which is usually red and contains a certain amount of quartz. Viewed from a distance, the junction between the magnetite and the footwall-porphyry seems generally to be well-defined, but, on a nearer approach, a passage-belt from pure porphyry into pure magnetite is perceived, and occasionally clean-cut dykes of magnetite are seen to have penetrated the igneous rock. The magnetite belongs to two generations: (1) properly bounded crystals which lie within the felspars, and are the probable result of primary differentiation; and (2) magnetite of "secondary immigration," which has partly flowed round the felspars, and has partly invaded them along the cleavage-cracks. At the junction of the porphyry and the ore, a belt of impregnation is of most frequent occurrence; comparable, in some cases perhaps, in structure with a net, the meshes of which would be formed by magnetite and the interstices filled up with porphyry; comparable in other cases with a breccia, whereof the groundmass is a compact magnetite, amid which are dispersed angular, highly-uralitized fragments of porphyry. The ultimate member of the series is a rock which in hand-specimens appears to consist solely of black magnetite and green hornblende; such specimens are to be found in the Tuollavaara deposit, but always at the junction with the country-rock, not in the midst of the ore-body. The ore-body of the Kiirunavaara attains a maximum thickness of 830 feet, but on the whole the thickness varies between 112 and 500 feet. Prof. J. H. L. Vogt has estimated that the amount of ore present in that ridge, and under the Luossajärvi lake down to a depth of 1,000 feet, and then in its continuation in the Luossavaara ridge, attains a combined total of 750,000,000 tons, whereof only 100,000,000 tons are to be got by opencast working. The ore is tough and hard, consists mainly of pure magnetite, more or less intermingled with apatite, and contains from 67 to 71 per cent. of metallic iron. There is no ferruginous gossan, as all the weathered stuff was swept clean off the surface by the glaciers which ground their way over the country in prehistoric times.

Tuollavaara was mantled over by ground-moraine, which has now been removed, and reveals a rocky eminence worn quite smooth and polished by ice-action. A great dark mass of magnetite, magnificently striated, crops out amidst the porphyry: the direction of the striae in this neighbourhood is from south-west to north-east, showing that the glaciers came down from

the Kebne Kaisse (altitude 7,000 feet), the highest mountain in Sweden. The annual output of ore from Tuollavaara alone is estimated to reach 70,000 tons. Besides the ubiquitous apatite and the asbestiform hornblende of the impregnation-zone, other associates of the ore are calcite, rarely quartz, still more rarely talc, brownspar (chalybite), iron-pyrites, and titanite. The results of a microscopic examination of the acidic hanging-wall porphyry are detailed, and they show it to be of later age than the ore-body and the basic footwall-porphyry. The description of the rocks is followed by a very careful discussion of the various theories put forward in regard to the genesis of these ore-deposits, and the author assigns at length his reasons for concluding that the main mass of the ore is of epigenetic-magmatic origin ("a magmatic differentiate which made its way upward"); while the ore of the impregnation-belt may be compared with that of a contact-deposit. It is shown how the facts fail to fit in with any other explanation.

(2) *Die Eisenerzlagerstätte Gellivare in Nordschweden.* *By* O. STUTZER. *Zeitschrift für praktische Geologie*, 1906, *vol. xiv., pages* 137-140, *with* 2 *figures in the text.*

This paper opens with a bibliographical list consisting of 21 entries. The author, in the course of his journey through Scandinavia in 1905, visited the celebrated Gellivaara mines among others, and considers that there is no need to lay stress on their universally-admitted importance; but he points out that controversy still rages in regard to the genesis of the deposits. Nothing can end this controversy, short of convincing evidence that the country-rock is of eruptive origin; meanwhile the author thinks it advisable to set forth the data upon which he bases his own conclusions.

The ore, consisting, like that of Kiirunavaara, of magnetite and apatite, but differing therefrom in its granular crumbly texture, is as yet mostly worked opencast in a small ridge or range of hills rising to an altitude of 2,025 feet above sea-level. The deposit furnishes undoubted evidence of recrystallization under pressure, and so does the country-rock, consisting chiefly of gneisses. Of these, and of the so-called granite and pegmatite, rocks rich in quartz which traverse the ore-body, a detailed description is given. Both the ore-deposit and the country-rock have slaty cleavage, and the general strike is east and west, while the dip is to the south at a very high angle, approaching indeed the vertical. Inclined as he was at first to regard the Gellivaara deposit as of sedimentary origin, a closer view induced the author to change his opinion, and the analogy with Kiirunavaara points to a common origin for both deposits. The lie of the deposits, the mineralogical character of the ores, and the nature of the country-rock, all tell in favour of the epigenetic theory. This may be considered as already proved in the case of Kiirunavaara, where the ore is a magmatic dyke, the outcome of deep-seated magmatic differentiation. And the Gellivaara deposit is a metamorphosed example of this, associated with very marked lateral impregnation.

(3) *Die Eisenerzlagerstätten bei Kiruna.* *By* O. STUTZER. *Zeitschrift für praktische Geologie*, 1906, *vol. xiv., pages* 140-142, *with* 1 *figure in the text.*

The author describes at some length a hand-specimen of brick-red porphyry, encircled successively by pale apatite, a ring of magnetite, and lastly, pale apatite again, from Luossavaara. He argues that it furnishes additional proof of the epigenetic (magmatic) origin of the deposits, and that it also shows that the apatite and magnetite must have simultaneously made their way upward from their deep-seated birth-place. L. L. B.

GRAPHITE-DEPOSITS IN LAPLAND.

Anorganische Graphitvorkommen in Lappland. *By* O. STUTZER. *Centralblatt für Mineralogie, Geologie und Paläontologie*, 1907, *pages* 433-435.

During a recent sojourn in Lapland, the author was furnished with information as to certain graphite-deposits which are being explored in the district whereof Svappavara is the centre, and specimens of the mineral were presented to him by the concessionaires. Already in 1899, Dr. F. V. Svenonius, of the Swedish Geological Survey, had mentioned graphite-deposits of no mean importance as occurring to the west, north-west, and east of Vittangi (a locality situated 17½ miles east of Svappavara). In one of these deposits (Palapöviö, east of Vittangi), 300 feet or so long and 16½ to 33 feet wide; the country-rock is a granulite traversed by pegmatite-dykes, and the graphite contains impurities in the shape of rock-inclusions. At Maltosrova, a deposit of excellent graphite, more than 300 feet in length and 15 feet in breadth, is found; it probably strikes across to the Äjärova hill, on the newly constructed main road, 7 miles west of Vittangi. This hill is built up chiefly of granite and syenite-granulite, and at its eastern base crops out a coarse-grained gabbro impregnated with magnetite: the graphite is said to occur at the contact with this gabbro. The mineral is traceable for 2½ miles farther north-eastward, as far indeed as Jälketkurkkio on the Torne-Elf; and it is from that locality that the specimens examined by the author were obtained: they include, besides pure graphite, gabbro (wherein the pyroxene is completely altered into hornblende) strongly impregnated with graphite. In place of the largely-decomposed porphyritic felspars, the microscope reveals a mosaic of small secondarily-formed plagioclases amid which the graphite forms a cloudy mesh: it is evidently of later formation than the secondary felspars, and with it is associated a good deal of magnetite. The occurrence of this graphite among and within igneous rocks is conclusive evidence of its inorganic (presumably pneumatolytic?) origin.

It is as yet too early to say whether the above-mentioned deposits are likely to assume industrial importance, but it may be well to bear in mind that several other graphite-deposits are known to exist in Lapland—at Skatamark, at Tallberget on the Öre-Elf, and at other localities. L. L. B.

AURIFEROUS DEPOSITS OF FINNISH LAPLAND.

On the Occurrence of Gold in Finnish Lapland. *By* CURT FIRCKS. *Bulletin de la Commission géologique de Finlande*, 1906, *vol. iii., No.* 17, *pages* 1-35, *with* 15 *figures in the text, a frontispiece and a map.*

This paper embodies the results of investigations made by the author in the course of a three months' sojourn in Lapland; but, for the sake probably of completeness, he gives an account of the placer-deposits based on the work of Mr. E. Sarlin, while his own studies were directed more particularly to the gold-bearing veins. During the period of 30 years which elapsed between their first active working in 1870 and 1900, the alluvia along the rivers Ivalojoki, Sotajoki, Palsinoja, Tolosjoki and Luttajoki, with their respective tributaries, yielded an average output of 460 ounces of gold. The auriferous district is, on the whole, mountainous, while the rivers are fringed by bogs, occasionally of considerable extent. The morainic drift which nearly everywhere covers the land, attains a thickness exceeding 30 feet, and the underlying rock is often weathered to a great depth. The gold-diggers in these parts distinguish

* *Nuddelanden from Industria-styrelsenin Finland*, 1902.

three varieties of occurrence: (1) the terrace-gold, in the gravel which covers the slopes and bottoms of the valleys; (2) the bottom-gold (*bottenguld*), on the fissured and uneven surface of the bed-rock underlying the gravel; and (3) the bank-gold, in the "banks" (deltas or fans?) deposited by the rivers at their mouths, as, for example, in the case of the Sotajoki, or at favourable meanders, as, for example, in the case of the Ivalojoki. Occasionally the rivers have cut a new channel through these "banks," and thus repeated the ore-dressing process. The gold-bearing strata are often discernible by a rusty coloration, due to the presence of hydrates of iron. The bank-gold is finer-grained and more waterworn than the other two varieties; in the actual output from the alluvial diggings the terrace-gold bulks by far the most largely. Generally speaking, these auriferous alluvia average some 20 inches in thickness, but in places they attain a maximum of 7 feet or so; in width they do not much exceed 6 feet, although sometimes a width of 50 feet has been proved. The tailings consist chiefly of iron-ore, both magnetic and non-magnetic, and garnet; at some localities monazite and a little zircon also are found in them. The biggest nugget ever got in the district, and that not of pure gold, weighed barely 3 ounces. In the summer of 1905, traces of platinum were observed in several of the placers; and thirty years before that, Dr. G. Svedelius had predicted that the mother-lode would be found not far from traces of platinum, in these localities where the placer-gold is most abundant, is coarsest-grained, and at its highest point above river-level. His predictions have now been verified.

The country-rock of the auriferous lodes may be designated generally as a granulite, although the type varies from place to place. Taking as an example the Vahtamaapää rock, this is a micaless schistose variety, made up of quartz and felspar, interspersed with small garnets, the diameter of which sometimes exceeds an inch. Another variety, rich in biotite, assumes rather the aspect of a granite-gneiss, while here the garnets diminish or disappear. In some cases graphite occurs among the accessory minerals. The granulites are intersected by dykes of coarsely-granular pegmatite, which passes little by little into pure white quartz, and of diabase or basalt. True fissure-dykes of later age traverse the country for miles: they consist of a red fine-grained quartz-porphyry, and their genetic connexion with the auriferous lodes is highly probable. In some localities the pegmatite-quartz dykes have attracted the attention of prospectors because of the occasional occurrence of pyrite in them, but in no instance can they be regarded as the mother-lodes of the placer-gold.

Before proceeding to the description of the lodes, the author directs attention to the climatic difficulties which confront the miner and the explorer in that far northern wilderness. The heavy winter snowfall, the spring thaws, and the frequent deluges of rain in summer sweep whole masses of gravel and sand into the diggings, and drown many an exploration-shaft. Such were the experiences encountered by the author himself in the summer of 1905. Full details are given of sixteen lodes, and they may be summarized as follows: in thickness they average 16 to 20 inches; they strike uniformly north and south, and dip very steeply (75 to 85 degrees) eastward or westward; the structure is frequently brecciated, but sometimes banded, showing the order of deposition of the minerals; and the yield in gold is low, averaging less than 31 grains per ton. The lodes consist primarily of quartz, siderite, calcite, specular iron-ore, magnetite, and pyrite, while magnesite and chalcopyrite are accessory minerals. There are, further, at the gossan or outcrop such decomposition-products as limonite and malachite. In general character the auriferous lodes of Finnish Lapland may be said to differ from any as yet discovered

elsewhere; their relative poverty, as compared with the placers derived from them, leads to the hypothesis that the placer-deposits are largely the outcome of a long period of pre-Glacial erosion and concentration of the gold extracted by natural processes from the lodes. The constitution of the lodes was such as to favour rapid formation of a gossan, and the zone of decomposed ores in pre-Glacial times was probably of considerable depth, but the greater part of it was destroyed by the inland ice during the Glacial period, the gold being scattered over a wide area of morainic drift. But at places where the conditions were favourable, near to the valley of a river . . . . the fragments of the gossan were transported to a point where in the post-Glacial period the renewed ore-dressing began, and so contributed to the formation of the placers. L. L. B.

MANGANIFEROUS AND OTHER ORE-DEPOSITS OF NIZHNE-TAGILSK, RUSSIA.

(1) *Gisements de Manganèse du District minier de Nizhne-Taguilsk.* *By* N. YAKOVLEV.

Within the domain of the Nizhne-Tagilsk works, six deposits of manganese-ore, including the Sapalsky mines, are spread over a distance of some 12½ miles. The ore is accompanied by brown hæmatites, and occasionally is found in immediate contact with the Devonian limestones. It appears to have been precipitated from solution in the course of a reaction wherein calcium-carbide was a determining factor. In three of the six deposits the limestones have been contact-metamorphosed by eruptive rocks, and have been so marmorized as to be practically impermeable to water, with obliteration of bedding-planes and joints, in such wise as to form less favourable *loci* for the deposition of manganese than the unmetamorphosed limestones. The two richest ore-deposits are connected with limestones that had undergone folding and fissuring such as to favour the circulation of underground waters and the precipitation of the particles of ore. The manganiferous deposits are not always found near the junction of the Devonian sedimentaries with the hornblendic igneous rocks (syenite, etc.), but sometimes quite in the midst of the latter. The author regards the hornblende as the primary source of the manganese.

(2) *Aperçu géologique du Domaine de Tchernoïstotchinsk, Arrondissement minier de Nijné-Taguilsk.* *By* A. KRASNOPOLSKY. *Bulletins du Comité géologique, St. Pétersbourg*, 1904, *vol. xxiii., pages* 345-400 *and* 1 *plate* (*map*).

The Chernoistochinsky works are situated south-east of Nizhne-Tagilsk, near the Chernaya, a left-bank tributary of the Tagil river, and the rocks of the domain are predominantly crystalline, sedimentary deposits occurring therein as mere patches. The alluvia along the Tagil are gold-bearing; platinum occurs along the Cháuzhe; magnetite is found among the olivine-rocks and diallage-bearing peridotites of the south-western portion of the domain; there are some unimportant traces of copper-ores; and finally, vast deposits of peat—a material of which the future industrial importance is not perhaps as yet fully realized. L. L. B.

AURIFEROUS DEPOSITS OF SERVIA.

Les Richesses minérales de la Serbie: I. Les Gisements aurifères. *By* DOUCHAN JOVANOVITCH. *Paris*, 1907, 107 *pages, with* 55 *figures in the text and* 1 *map.*

The author deals with the gold-fields of Pek, Mlava, Porecka and Timok, all situated in Eastern Servia, and separated one from the other by hill-ranges. In that region, many traces of the Roman occupation survive, and among

them those of the ancient gold-workings, and of the mint and goldsmith's furnaces of Viminacium. The history of the mineral-industry hereabouts is given in some detail, and then in the second chapter of his monograph the author describes the geology of the area.

The crystalline schists, which may be regarded as the basement-rocks of the country, form an extensive belt, interrupted in places by outpourings of eruptive rocks of all ages. In the Pek basin, the Palæozoic rocks are seen to overlie directly the crystalline schists, while the most considerable outcrops of Triassic sedimentaries in south-eastern Servia occur at Veta; there is some reason to infer a connexion between the latter and the occurrence of certain metalliferous ores (copper, etc.). Jurassic and Cretaceous sedimentaries are also well represented; while, in the Pek and Timok basins (the latter more especially), the gold-placers consist for the most part of sands and gravels of Tertiary age. Nevertheless, the Quaternary deposits play a more important part still among the Servian placers, their wealth in gold being quite remarkable; and in the Timok basin the great diluvial terraces of loess, gravel, and sand attain a considerable height. Apart from the placers, there are several groups of parallel fault-fissures, infilled with gold-quartz, etc., which are undoubtedly connected with the various periods of vulcanicity through which the region has passed: these fissure-lodes have, generally speaking, a north-and-south strike; but their width is variable, ranging from 5 to 100 feet. They do not appear to have been proved, so far, to a greater depth than 330 feet.

It is more especially to the Tertiary eruptions of the middle period, the andesites, that the author is inclined to attribute the advent in their greatest intensity of the metallic sulphides with the concomitant precious metal. The emanation of auriferous sulphides of copper and iron came to an end in the third eruptive phase, when perhaps there was a correspondingly more intense emanation of sulphides of lead, zinc, and antimony, such as those found at Believina, Bela-Reka, Maidan-Pek, and Kucajna. The products of slow sublimation have been concentrated in the cavities of the limestones, especially at their contact with the andesites; thus, in the Angelina cavern at Kucajna, a mass of 247,170 cubic feet of auriferous lead-ore has been found. The author dwells complacently on the richness of the placer-deposits (sands, gravels, etc.), the metalliferous particles of which are derived from these fissure-lodes, cavities, and pockets; and mentions that the three dredges which are in regular operation at Neresnica, in the Pek valley, are yielding excellent results.

In the third chapter, he gives what he terms a mineralogical synopsis of the subject. A native amalgam of gold, known to the Servian miners as *Zhivak* (from *zhiva*, mercury), occurs in rounded, whitish grains, in association with red granules of cinnabar in the placer-deposits; and, wherever these two minerals are found, there also magnetite appears in great quantity. The alluvial gold of eastern Servia is always more or less argentiferous: it occurs variously as fine dust, in thin flakes, slender needles, granules, and nuggets averaging in size that of a hazel-nut. The importance of the association of gold, in the primary deposits, with the sulphides of copper and iron, has already been hinted at. In the St. Ann mines of Deli-Iovan, for instance, where masses of compact iron-pyrites occur, the richness in gold increases concurrently with the quantity and hardness of these masses, which indeed are cemented together by quartz containing native gold. The average yield, calculated from a vast number of assays of samples from these mines, ranges between 370 and 432 grains per ton. Although the association of chalcopyrite is perhaps generally of less importance in eastern Servia than that of iron-

pyrites for the occurrence of gold, yet in certain districts it takes the premier position, as at Majdanpek (an important copper-mining centre), Bor, and Zlot-Brestovac. The association of the gold with arsenical pyrites, galena, cinnabar, calamine, limonite, magnetite, and quartz, respectively, is discussed; and we then come to the fourth and final chapter, in which the author deals with the geographical distribution of the gold.

Taking first the Pek basin, after a glance at the auriferous localities of Leshnica and Kaona, and a hint that the installation of two gold-dredges in the broad valley of the Pek, between the latter village and Turiya, would pay, a description is given of the Kucajna mines, situate some 22 miles south of the river-port of Veliko-Gradisté on the Danube. Exploration-work has only touched here about a tenth of the total area pegged out, and has not been carried in depth more than 160 feet below the surface; yet there is no question that the deposits are very rich, and the Pek river here would furnish motive-power estimated at 60 horsepower. During the short period that was devoted to mining operations, 270 tons of lead, 33 tons of zinc, 54,687 ounces of silver and 2,765 ounces of gold were got from these mines. The author describes at some length the mining operations which are being carried out by a British company at Neresnica (gold-dredging, as above mentioned) and elsewhere; and statistics are given of the output obtained by means of the dredges in the years 1903 to 1905. The Sveta-Varvara (St. Barbara) mines, on which exploration-work is still in progress, are expected to yield a minimum of 400 grains per ton. The Majdanpek mines, to which allusion has already been made, are in the hands of a Belgian company.

After a brief survey of the Mlava basin, the author passes on to the Porecka-Reka basin, where the only important localities for gold so far known are Crnajka and the neighbourhood of the village of Luka. In regard to the Crnajka valley, the difficulties of working the deposits would be very great, otherwise than by a method of combining excavators and dredges, a combination which has yielded good results in Siberia.

In the Timok basin, the Deli-Iovan deposits, both primary and secondary (or placer-deposits), have already been mentioned. But the Crna-Reka district, where the gold occurs amid the andesites, is of fully equal importance from the miner's point of view, and in the Timok valley itself auriferous deposits extend from Vratarnica up to the head-waters of the river.

A Servian-French vocabulary is given of the principal terms in use among Servian miners, and notice is published that in a second memoir the author will deal with the cupriferous deposits of the country. L. L. B.

MERCURY ORE-DEPOSITS OF AVALA HILL, SERVIA.

Die Quecksilber-Lagerstätten am Avala-Berge in Serbien. *By* H. FISCHER. *Zeitschrift für praktische Geologie*, 1906, *vol. xiv., pages* 245-256, *with* 17 *figures in the text.*

The Avala hill, some 12½ miles south of Belgrade, is built up of unfossiliferous marly limestones of Cretaceous age, traversed at various points by biotite-trachytes. Southward of this hill stretches a serpentine-tract, amid which crop up at six localities rock-masses essentially consisting of chert or of a fine-grained brownish-grey, or white quartz intergrown with ferruginous dolomite (brownspar) and carrying mercury-ores. A characteristic constituent of these rock-masses is the chromiferous potash-mica, described by Dr. — Lossanitsch under the name of avalite. Rather over half a mile to the south-west of Mala Stena (one of the six localities just mentioned), along the Ripanj river, and near the junction between serpentine and limestone, yet

other dolomitic quartzose rock-masses are ranged lineally one behind the other, characterized by an especially high percentage of dolomite, and carrying at one point a small quantity of galena. The quicksilver-ores are only found here in the form of rolled pebbles.

The ore-deposits were discovered in 1882, when the Servian railway, from Belgrade to Nisch, was in course of construction. Up to the year 1887, they were worked only on a small scale, but thenceforward until about 1891, operations were conducted on a fairly large scale. Von Groddeck had, in 1884, described the quartzose masses as lodes; but the adits driven in the course of exploration-work through the rocks, showing the avalite-quartz-masses to be on all sides enveloped by dark-green serpentine, are held to have disproved this view. There seems, however, to be little doubt that the deposits are the outcome of the metamorphic alteration of serpentine by thermal alkaline springs, containing in solution silica and carbonates and so forth; like the original serpentine the quartz-masses contain pisotite, chrome-iron-ore, etc. The adit driven at Schuplja Stena moreover proved the absence of a distinct junction-line between the serpentine and the avalitic dolomite-quartz rock; indeed, the former passes into the latter so gradually, that it was often impossible to tell in the mine where the one began and the other ended.

The author gives a petrographical description of the serpentine and the passage-rock (opalinized serpentine), likening the latter to the matrix wherein the Bohemian garnets occur, with the difference, however, that no olivine is to be found in the Servian rocks here described. Nevertheless, the mesh-structure of the serpentine indicates its probable derivation from a peridotite. The films and granules of cinnabar and the associated specks and crystals of pyrites found in the quartz are connected with fissures which were evidently opened up within the quartz-masses after the metamorphic process was complete. These fissures, varying repeatedly from a mere hair's breadth to a width of 16 inches, are infilled with a gangue of white, coarsely crystalline quartz and heavy spar, in addition to the ores just mentioned: calcite is of rare occurrence. In the immediate neighbourhood of the fissures, the quartz is so strongly impregnated with cinnabar that one may almost speak of pockets or nests of ore; in the fissures themselves cinnabar occurs in granular or crystalline compact masses, and encrusting geodes in the form of lustrous cochineal-red crystals. Calomel, of later formation than the cinnabar, also occurs; and native mercury, in the form of innumerable little globules, is a frequent associate of both minerals. The chronological sequence of the minerals in the fissure-veins would appear to be: (1) quartz, heavy spar, pyrites; (2) cinnabar, mercury oxychloride (?kleinite), calomel, native mercury; (3) younger quartz, younger baryte; and (4) younger cinnabar, younger pyrites. The hypothesis that an enrichment of the ores would be traced in depth has been unfortunately falsified: the richest and most extensive ore-bodies were found at Schuplja Stena at the horizon of the Jerina adit (130 feet below the surface) and at the third 'tween level; but at the deep-level horizon the quantity of ore and its richness in quicksilver proved to be inferior to what had been found at higher levels.

The suspension of mining operations is consequently not due to want of the necessary capital for pursuing exploration-work; but because the deposits are in themselves of small extent, and offer no prospect of any improvement as one goes deeper down. Between 1885 and 1891, it is reckoned that 7,796 tons of ore were got, yielding very nearly 176,000 pounds of metallic mercury.

The genesis of these Servian quicksilver-ore deposits is said to be analogous to that of the Californian deposits. L. L. B.

ORE-DEPOSITS OF THE PROVINCE OF ALMERIA, SPAIN.

(1) *Vorkommen, Gewinnung und Aufbereitung der Blei- und Kupfererze des Pinar de Bédar in Süd-Spanien.* By O. Pütz. *Zeitschrift für das Berg-, Hütten- und Salinen-wesen im preussischen Staate*, 1906, *vol. liv., Abhandlungen, pages* 675-683, *with* 10 *figures in the text.*

The Sierra de Bédar, in south-eastern Spain, is built up of those crystalline schists, belonging to the Middle Archæan division, which play so important a part in the structure of the Spanish sierras as a whole. They probably nowhere occur in their original position, but are highly disturbed and plicated, and often surround masses of foreign rock, into which such bedding as they exhibit appears to pass. Mica is so enormously abundant in them, as often of itself alone to cover wide areas containing quartz only in microscopic inclusions. This characteristic occurrence of mica perhaps explains the absence of actual fissures and overthrusts, whereas plications of every kind in the Sierra de Bédar are past counting. In good hand-specimens, the effects of pressure may be traced into the tiniest venules of the mica. The most numerous rock-masses included among the schists consist of limestones of extremely variable texture and composition, and of gneiss generally exhibiting a fibrous structure.

In the neighbourhood of the village of Bédar, a brown hæmatite-deposit is worked, which is most probably the decomposition-product of a spathic iron-ore formed by metasomatic replacement of limestone. In point of fact, a passage is over and over again distinctly traceable from the partly compact, partly crystalline, dolomitic, marmorized limestone into a brown hæmatite containing 60 per cent. and more of metallic iron. Fine pseudomorphs of limonite after pyrite and siderite occur in this deposit.

Pinar de Bédar, the locality where the copper- and lead-ores have been found, lies in the eastern part of the sierra, towards the sea. The exposed rock consists of highly weathered, occasionally very crumbly, earthy limestone. It is unfossiliferous, and is undoubtedly of Archæan age, as proofs of its intercalation among the crystalline schists are forthcoming. The metalliferous ores occur as impregnation-zones in this limestone, sometimes so poorly mineralized that it takes a very keen eye to detect them. The sole representative of the lead-ores is galena, which is of very widespread occurrence, usually in its well-known cubic crystalline form. The percentage of metallic lead and silver that it contains is extremely variable. The copper-ores are not found as sulphides, but as the carbonates, malachite and azurite, which (like the galena) occur in great abundance and are invariably associated; structurally, they belong as a rule to the compact and earthy varieties, and are seen sometimes with the galena, sometimes apart from it. Their genesis, like that of the brown hæmatite already mentioned, may be traced to the upward percolation of thermal waters charged with carbonic and sulphuric acids, in the moribund phase of comparatively recent volcanic outbursts: the difference being that, whereas the iron-ore metasomatically replaced portions of the fissured limestone, the plumbic and cupric precipitates were deposited in all such cavities and clefts as were available in that rock. From the point of view of horizon, the copper- and lead-ores cannot be said to occupy a definite belt, but are somewhat irregularly distributed. Enrichment can, however, be traced along a general line of strike from north to south. The ores are not traced deep down in a vertical direction, for the fissuring and "cavernosity" of the limestone are but shallow or superficial phenomena, and with increased depth the limestone becomes more compact and barren of ore.

These occurrences are hardly such as to admit of mining operations on

the grand scale; but they are well suited to the system, so beloved of the Spaniards, of leasing out concessions in small parcels to separate lessees or *partidarios*, each of whom works his plot, either with the help of his family or with that of hired labour, on his own account. Thus a great number of small shafts and headings are huddled together in a comparatively restricted area; and winding is performed by means of a wooden hand-winch with esparto-rope, the ore being brought up in baskets, also woven of esparto-grass. The miner is conveyed, sometimes down to depths of 160 feet and more, by the action of the same winch and rope. Boys alone act as hauliers, carrying the ore-baskets on their backs through the low and narrow workings. Many mines, however, are worked opencast; and, where not, they are generally confined to shallow depths and to the loose cavernous limestone. In point of fact, the percentage of attainable profit would hardly repay an extensive use of blasting-materials.

Quite an infinitesimal proportion of the ore thus brought to the surface (and then only the copper-ore) is sufficiently pure to be shipped without further treatment. The overwhelmingly greatest part of the output, including all the galena, has to undergo a preparation for the market, which constitutes really the main work of the mining folk. In view of the small scale on which operations are conducted, this involves, of course, manual labour pure and simple, and some of the most primitive appliances conceivable. But the industry, skill, and punctilious carefulness with which that labour is performed enable the miner to achieve results such as no mechanical appliance could rival. It is true that the losses involved in washing the ore are sufficiently considerable to enable a *partidario* frequently to work with profit over again the tailings or waste-heaps left by his predecessor. The successful results are perhaps especially due to the unshakable perseverance of these Spanish miners, in the monotonous repetition of the various stages of the purifying treatment. This treatment is based on the same principles as those adopted in far larger establishments: hand-picking, trituration, sifting, and washing in appropriate tanks follow one another in chronological order. As a general rule, however, the granular condition in which the stuff reaches the surface precludes hand-picking; and the raw material is thrown at once on to a sieve, consisting usually of iron rods, between each of which is a space measuring 0·8 inch. The material that fails to pass through this sieve is tipped into a circular space some 6½ to 10 feet in diameter, bounded by large stones, and two or three boys, wielding iron crushers, go on for hours rhythmically triturating the material, apparently insensible to fatigue and to the torrid heat of the southern sun. In a few isolated cases, rollers (similar to those used in some German mines) set in motion by a beast of burthen, are employed in the trituration-process. The crushed material is then placed in a sieve, which is worked up and down for half a minute to a minute in a wooden *kasten* containing water, with the result that all the fine particles are precipitated to the bottom of the *kasten* or recipient. The coarse ore remaining in the sieve is raked off, and subsequently resifted as many times as may be necessary. When sufficient fine ore has collected at the bottom of the *kasten* or *estanque*, the water is drained off, and the ore is accumulated in a heap, until there is enough of it got together for the process of final washing on a rimmed plank-flooring which rests simply on the surface of the ground. Water is introduced through an opening in the rim, an inch or two above the floor-level, and the pulverized ore is stirred up in the water which streams across the slightly inclined floor into a settling-tank by a man wielding a sort of long-handled hook (*rodillo*). Apparently the system is so contrived

that the same water is used over and over again. Without following the author further into the detailed description which he gives of this stage of the process, it may be sufficient to note that it results in a considerable enrichment of quite poor ores, amounting to as much as 40 or 50 per cent. on an average. The daily output per man employed in this very tedious work hardly exceeds 40 pounds of ore, remembering that the labour-day is one of 12 hours, and that work is done on Sundays, just as on week-days. When it is a question of piece-work, as in the industry here dealt with, the Spaniard is diligent beyond cavil, and, furthermore, his temperate habits are well known.

(2) *Über einige Erzlagerstätten der Provinz Almeria in Spanien.* *By* BARON F. FIRCKS. *Zeitschrift für praktische Geologie*, 1906, *vol. xiv., pages* 142-150, *with 5 figures in the text.*

Geologically speaking, the province of Almeria, at the south-eastern extremity of Spain, is built up of Archæan schists, Triassic and later rocks, and sub-recent deposits. Older eruptive rocks play a secondary part among the schists, while the newer eruptives, following a great fissure- and fault-line, strike along a belt parallel with the coast from Cabo de Gata to Cabo de Palos, a distance of 125 miles. There is an undoubted connexion, between the occurrence of the metalliferous ores in these parts, and the younger eruptives and the associated hydrothermal phenomena. It was amidst the flows of andesite, dacite, liparite, and trachyte that the Carthaginians and the ancient Romans pursued active mining operations; and, after generations of death-like torpor, the mineral-industry hereabouts has recently sprung into vigorous life again.

After a brief sketch of the general geology of the region, the author proceeds to describe the galena, copper, and iron-ore-deposits of the Sierra de Bédar and of Coscojares, those of the sierra being by far the most important. Here galena and carbonates of copper form the cementing-material of a limestone-breccia, whereas the oxidic iron-ores are intercalated as a bedded deposit between a marmorized limestone and the gneissose mica-schists. The wealth of lead- and copper-ore diminishes notably in depth, and the deepest workings hardly go beyond 325 feet down. Trial-shafts pushed to a greater depth have struck very feebly metalliferous limestone. The galena hardly ever occurs in a decomposed condition, or altered to carbonate; while, on the other hand, the sulphidic ores of copper have never been found, their carbonates only being known here. Veins of barytes traverse the limestone in many places, and are frequently carriers of copper-ore. The proportion of silver in the galena varies enormously; where the galena occurs alone there are barely 11 ounces of silver in a ton of 50 per cent. lead-ore, but where copper-ores are associated with the lead, as much as 32 ounces of silver may be found in the ton of ore. The nature of the occurrence is such that it favours individual working on a small scale, and when good prices are obtainable a total monthly output (from about 200 workings operated by manual labour exclusively) of 300 tons of 45 per cent. galena and 250 tons of copper-ore containing 5 per cent. of the metal, may be reached. There seems to be no doubt that the origin of these ores dates from the older Quaternary time, when thermal springs (some of which are still in existence) made their way up through clefts and fissures in the eruptive rocks, and, rebuffed by the recalcitrant schists, deposited their metalliferous particles among more easily attackable rocks, such as limestone. That the plumbiferous solutions, at any rate, did not actually decompose the limestone is evident, since the fragments of breccia cemented by lead-ore have preserved their original angularity.

West of the galena-mines of the Pinar de Bédar, lie the neighbouring iron-ore workings of Serena, the geological relationships of the latter being all but identical with those of the former, although there is perhaps more evidence of disturbance and faulting. The main bed of limestone here averages 65 to 100 feet in thickness, occasionally much exceeding this, and sometimes also pinching out to nothing. In places it is overlain by thin bands of Triassic limestone and conglomerate, showing here again an analogy to the Pinar de Bédar occurrence. The limestones intercalated among the schists are the carriers of the iron-ore, the richest accumulations being usually at the junction of the two rocks (schist and limestone); but this by no means implies that the contact-zone generally is mineralized. In relation to its total extent, in fact, the mineralized portion is quite small. Where mining operations, however, are now in full activity, practically a third of the contact-zone proves to be workable. In the deep-level workings, the thickness of payable ore varies from 10 to 16½ feet. Apart from the contact-zone, certain portions of the limestone itself appear to have passed by metasomatosis into iron-ore. The payable stuff may be defined as consisting of the several varieties of brown iron-ore, with which are secondarily associated such minerals as pseudomorphs of limonite after pyrites and siderite, native copper, malachite, barytes, etc. The working is done by pillar-and-stall; and, on account of the rotten condition of the roof, a very complete system of packing has to be resorted to. The ores are carried down by means of a Pohlig cable-railway, 10 miles in length, to the harbour of Garucha, where they are put on board ship. The average annual output from 1893 to 1903 inclusive has been 100,000 tons. The crude ore of the opencast workings assays to 48 per cent. of metallic iron and 15 per cent. of silica; the normal ore averages 58 per cent. of iron and 3 to 5 of silica.

Northward of the Serena mines, lie a vast number of concessions of which only a portion is worked, the most important being perhaps the Tres Amigos and La Feria mines.

It seems evident that these brown iron-ores are in almost every case the decomposed outcrops of deposits of spathic iron-ore, which latter have been formed by metasomatosis. They are not to be regarded as the ferruginous gossans of lead, silver, and copper-ore-deposits; and it is highly probable that the singularly uniform belt of iron-ore-deposits, which extends along the shores of the Mediterranean (eastern coast of Spain and northern coast of Africa) and along the western coast of France, owes its origin to the upwelling of thermal ferruginous solutions at an epoch quite distinct from that during which the other metalliferous ores were formed: yet, although distinct, it was not perhaps very much earlier.

(3) *Über einige Erzlagerstätten der Provinz Almeria in Spanien.* [*Part II.*] *By* Baron F. Fircks. *Zeitschrift für praktische Geologie*, 1906, *vol. xiv., pages* 233-236, *with* 1 *figure in the text.*

As in almost every other mining district in Spain, the ancient Romans were the first to prospect and work over the ore-deposits of the Sierra Almagrera (province of Almeria). After many vicissitudes there has been of late a revival of the mineral-industry in that neighbourhood, in part owing to the success with which German engineers have solved the problem of unwatering the workings. The sierra ranges for over 5½ miles, sensibly parallel with the coast, to which it presents a steep scarp, and reaches its greatest altitude (1,200 feet) in the Puntal del Ruso. Somewhat less than 2½ miles in breadth, the sierra is largely built up of phyllites, in part metamorphosed, from among which rise here and there wall-like reefs of quartz. Banked up against the

spurs of the sierra are the Tertiary limestones, marly and sandy clays, sandstones, and conglomerates, while the western flank of the range is characterized by a belt of younger eruptive rocks which appear to be the ore-carriers. The metalliferous lodes all but universally strike north-west and south-east (the sierra trends from north-east to south-west) with a north-easterly dip, but their longitudinal extent rarely exceeds a thousand yards or so. In point of fact, two complexes of lodes can be traced, of which the older is by far the richest and the most important; while the newer, in many respects, not least in the low percentage of silver, recalls the sulphidic lead-veins of Freiberg. The principal ore is a highly argentiferous galena, almost everywhere occurring in the form of octahedral crystals. Pyrites, blende, and the fairly abundant bournonite play a secondary part. Nearer the surface native silver, and its combinations with chlorine and iodine, as also copper-pyrites and its decomposition-products, are met with. The gangue chiefly consists of yellow chalybite, heavy spar, and fragments of the country-rock; calcite occurs as an accessory. In several mines the chalybite occurs in such quantity and of so pure a quality, that it pays to work it as an iron-ore and smelt it for export. In some cases there is so microscopically minute an intermixture of the chalybite and galena (locally termed *molineras*), that the observer might well rush to the conclusion that he has before him a new mineral, hitherto unrecorded. The richest ores, perhaps, have been got at middling depths, reckoning from 328 feet below the surface to the underground water-level of the country. The two most important localities in the sierra (from the miner's point of view) are in the Jaroso valley and in the Franzes valley. Here are found the highest percentages of silver and the richest lead-ores, while as one recedes from them the ores are seen to pass into pyrites and poorer galena, and gradually to disappear altogether. The best lodes occur on the eastern flank and on the crest of the sierra, while on the seaward scarp the lodes are few in number and insignificant in quality. The Jaroso main lode is known to extend over 2,000 feet, it is 33 feet thick, and has yielded by far the greater portion of the total lead and silver output of the district.

The iron- and silver-ore-deposits of Herrerias, situated at the base of the Sierra Almagrera, are as closely connected with that sierra from the geological standpoint as they are from the topographical. The phyllites, masked here by Triassic limestones and shales, these again being mantled over by Tertiary loams and conglomerates, are struck at Herrerias (1¼ miles distant from the sierra) at a depth of 650 feet below the surface. The principal ore of this district is an iron-ore remarkable for the high percentage of manganese which it contains. The richer ores, assaying to 50 or 60 per cent. of metallic iron and 6 per cent. of manganese, are nearly always in a soft, crumbly condition, while the poorer ores, hard and coarse-grained, occur wherever the compression of the limestone has been incomplete. The ore-deposit, associated as it is with the contact-zone of limestone and shale, is of metasomatic origin, like most other iron-ore-deposits of the province of Almeria, recalling indeed those of Bédar, previously described by the author.

The occurrence of rich silver-ores and native silver is of supreme importance for the Herrerias district. Frequently does it happen that an iron-ore deposit is overlain by loamy beds which are so impregnated with silver-ores that samples have yielded a *minimum* of 100 parts of metallic silver per million (3·2 ounces per ton). The sandy layers are not seldom highly silicified, and in such cases are particularly rich in silver. The iron-ore itself is seamed by a number of veins and venules, mostly infilled with heavy-spar, which

ramify and nip-out in the overlying loamy beds. The silver-ores are undoubtedly derived from thermal springs similar to those which formed the Almagrera lodes. The succession of events was probably somewhat as follows:—Upward percolating ferruginous solutions transformed the limestone into carbonate of iron, and accessorily into sulphides of iron. This metamorphosis was naturally most active where the way lay most open to the ferruginous solutions, that is, at the contact between limestone and shale. The iron-ore deposit having been formed, further mountain-movement took place with consequent fissuring. Long fissures were easily opened up in the slates of the Sierra Almagrera, but encountered another sort of obstacle in the altered and originally soft deposits of Herrerias; here, therefore, a network of fragmentary lodes was formed rather than a regular series of big lodes, although the mineralogical composition of the former is practically identical with that of the latter. If lodes were formed with difficulty among the iron-ores and limestones of Herrerias, still more would that be the case with the overlying loamy deposits: in these no fissures could properly form, and intimate impregnation with silver-ores was the consequent alternative. At Herrerias, as in the Sierra Almagrera, evidences of the mining industry of the ancient Romans abound. About the middle of the nineteenth century, as in the case of the Sierra Almagrera, there was an industrial revival which lasted for several years; nowadays, however, there is a woeful falling-off, and but few mines can boast an output of much importance as regards silver-ores. In regard to the iron-mines, it is another story altogether—quite a number produce large quantities of ore, and there are prospects of a still greater output for many years to come. L. L. B.

HUELVA PYRITES-DEPOSITS, SPAIN.

Beiträge zur Kenntniss der Huelvaner Kieslagerstätten. *By* **Bruno Wetzig.** *Zeitschrift für praktische Geologie*, 1906, *vol. xiv., pages* 173-186, *with* 13 *figures in the text.*

It would seem that the scientific description of these deposits, so far as well-digested published matter is concerned, has hardly kept pace with the extraordinary activity of the mining operations of which they are the object. So rapidly are they being worked that the author fears, that in the case of many a mine, the last shift will have completed its task ere the man of science finds the opportunity of gleaning his own little harvest of data as to exposures, etc., therefrom. Much printing-ink has, it is true, been expended on Huelva (more especially on Rio Tinto), mostly in the form of traveller's impressions hurriedly jotted down in the course of a few days' visit. Perhaps the only solid contributions that have been made to the knowledge of the subject within the last twenty-five years are the accounts published by Messrs. J. H. L. Vogt, Klockmann, and Gonzalo y Tarin respectively. The theory of the sedimentary origin of the deposits enunciated by the second of the above-mentioned authors appears to have held the field until recently; but now that the champions of an epigenetic or metasomatic origin have entered the lists, Mr. Wetzig thinks it incumbent upon him to break a lance with them. Dight in the full panoply of notes and sketches, amassed in the course of a quarter of a century's residence in the province of Huelva, during five years of which he lived at the mines and almost every day was in and about them in his capacity of engineer, he enters the fray with a justifiable assurance of victory. He points out that it is rather an advantage that his own observations bear mostly on the smaller mines, as it is in these smaller mines that

the general conditions can best be grasped and studied as a whole. The gigantic scale of everything in the larger mines renders a bird's-eye view of the subject all but impossible.

The masses of pyrites occur on a plateau consisting chiefly of shales and apparently-stratified eruptive diabasic rocks, with a little grauwacke, and still more rarely limestone, rising towards the Sierra de Aracena to an altitude exceeding 1,300 feet above sea-level. The rocks have been much overthrust and disturbed, their general strike is from east to west, and they dip almost invariably northward. The plateau is a plain of erosion, on the whole undulating with deep-cut river-valleys, while the hills which rise from it like islands are mostly built up of quartz or jasper, and have thus opposed a stout resistance to the agents of denudation. Recently, the well-known fossil *Posidonomya Becheri* has been found in various localities in the mining field; and the author regards it as extremely probable that all the rocks date from the period of the Kulm, although he afterwards says that certain eruptives rich in quartz which have affected the ore-body at the contact are undoubtedly of later age than the diabasic sills which have not affected the ore-body. Thus at San Telmo intrusive porphyries have twisted the strike of the pyrites-deposits and the neighbouring shales almost right round from east-and-west to north-and-south; at the Joya mine the columnar porphyry cuts through the centre of the ore-body, laying the western portion of it flat and squeezing the eastern portion into a pillowy mass. At La Caridad in Aznalcollar, the ore-body, which assumes the character of a seam, is repeatedly fissure-faulted in its western portion, while in the eastern portion where the porphyry comes into contact with the ore-deposit, the latter is nipped out or packed into folds.

The imposing spectacle of the great masses of ore of Rio Tinto and Tharsis, hundreds of feet thick, is apt to delude the observer into a belief in the complete unity of character and structure of the deposits. But a closer view reveals the existence of separate beds and lenticles of ore, alternating with wedges or lenticles of barren shale (*cuña de esteril*). Certain beds of ore are characterized by a higher percentage of lead and zinc, and some take on quite a banded structure, owing to the alternation of pyrites, blende, and galena, these bands being always parallel with the bedding. Other beds are characterized by a high percentage of copper in the form of chalcopyrite, and a consequently yellow coloration; yet others, on the contrary, consist of a very compact ore, containing but little copper and a high percentage of sulphur. Occasionally the pyrites is so interbanded with fine laminæ of shale, that it assumes all the appearance of the latter, and its true nature is only revealed by its specific gravity. Sometimes the shale predominates over the pyrites, such masses being known as *azufrones*; and there are some ores which are very difficult to break up, owing to the large amount of quartz associated with them. All the ore-bodies coincide in strike and dip with the shales among which they lie; they partake, too, in all the plications and disturbances to which the latter have, in the course of ages, been subjected. Particular belts of ore-bodies can be followed along the strike of the shales, such as that extending over a length of about 3 miles, which is worked in the mines of Carpio, Cruzadillo, Poytos, and Lomero. The several deposits are linked one with the other by brown ferruginous shales, which in depth prove to be impregnated with pyrites, and occasionally exhibit stringers or beds of massive pure pyrites. The author cites various other examples of similar ore-belts, and proceeds to point out the hopelessness of endeavouring, either to lay down rules as to the relation between the thickness of any of these

deposits and the amount of copper which they contain, or to calculate the form and extent of the lenticles by means of mathematical formulæ. On the other hand, the enrichment in copper of a given deposit may be gauged from the thickness of the ferruginous gossan which overlies it, taking also into account the amount of erosion which that gossan has demonstrably undergone. It is shown, too, how the richest copper-ore may be expected to occur rather at the floor, than at the roof, of a deposit; how, further, enrichment has sometimes taken place along fissures and clefts, which cut across the deposit transversely to the bedding. The miner translates the enrichment of the upper zones of a deposit which has a ferruginous gossan at the outcrop into terms of impoverishment with depth; thus, at Cabezas del Pasto, the ore at the 130-feet level contained on an average 3½ per cent. of copper, whereas at the 260-feet level it contained only 2 per cent. In the Caridad mine at Aznalcollar, the ore at the 130-feet level contained from 4 to 5 per cent. of copper, but at the 360-feet level only a half per cent. At Cuchichon, however, after impoverishment between the depths of 260 and 375 feet, an enrichment of the ore was observed thenceforward down to the greatest depth reached in the mine, that is, 500 feet; but this apparent exception is explained by a diagram. The author combats strongly the views of those who do not regard the ferruginous gossan as purely and simply the decomposition-product of the pyrites. He shows how the nature of the gossan is an index to the character of the underlying ore-body; where the former is a compact red hæmatite, the underlying pyrites is compact and poor in copper; where the gossan is yellow, porous, and ochreous, pyrites rich in copper may be looked for beneath it.

A deposit known as *toba*, bears in appearance an extraordinary resemblance to the gossan, and is often confused with it. The *toba* was formed in this way: the iron-sulphate waters, leached out of the original mass of pyrites, banked up in pools or lagoons, deposited their iron-oxide around pebbles of quartz and shale on the bottom, and thus a conglomerate with a ferruginous cement was built up. The gossan, on the other hand, would answer the description of a breccia of iron-oxides cemented by infiltrated silica. The *toba*, as a secondary deposit, does not occur on the spot where its materials were formed, and naturally coincides neither in strike nor in dip with the shales. It has been the cause of many erroneous notions as to the genesis of the ore-deposits. At the Rio Tinto mines, the *toba* forms a great plateau, the Mesa de los Pinos, in which remains and impressions of Tertiary plants are found. In the Caridad mine, the *toba* is seen to stand up in isolated reefs among the Eocene limestones, and is also seen to have been thrust downwards by the intrusive porphyry to a depth of 230 feet. At the same mine, conclusive evidence of the pre-Tertiary age of the ore-body is thus available, since, apart from what has just been said about the *toba*, the Eocene horizontally-bedded limestones overlie unconformably the uptilted ore-beds and shales. Data are also adduced from the Aznalcollar mines, to show that, in comparison with the age of the Huelva pyrites-deposits, the interval of time that has elapsed since the deposition of the Eocene limestones is of small account, so small indeed that the progress of the decomposition of the original ore into oxides of iron is hardly noticeable in that interval.

Recurring to the question of the genesis of the pyrites-deposits, the author holds that all the facts, of which a synopsis has just been given, constitute cumulative evidence in favour of the sedimentation-theory. He enumerates the several particulars which go to prove that the deposits cannot be lodes or infilled fissures, and then refers to the observed gradation from pure pyrites,

through more or less impregnated to absolutely barren shales, as further proof of the sedimentary origin of the ores. At the Monte Rubio mine, and near the hill of the Virgen de la Peña, at La Puebla de Guzman, the ore-body consists of shales strongly impregnated with pyrites, alternating with thin stringers and bands of pure pyrites, none of which exceeds 3 feet in thickness. The composition of the ore is identical with that of all the other pyrites-deposits in the province, only the accumulation of the pyrites has not been carried to the same pitch of concentration. Several similar instances are cited, all showing more or less the above-mentioned gradation.

The extraordinary shapes which the deposits occasionally assume, capricious as they were termed in the older text-books, are doubtless due in part to the subsequent intrusion of eruptive rocks, and in part to the dynamical effects of pressure and thrust.

In conclusion, the author devotes a few lines to the manganiferous deposits of Huelva. These occur in the same formation as the pyrites-deposits, and, like them, are conformably interbedded with the shales. In fact, all the conditions of their occurrence are remarkably similar, with the difference that the manganese-ores do not appear to continue in depth much beyond 65 feet below the surface. Very rarely do they attain a depth of 130 feet, and in the single instance of the Santa Catalina mine, close to the deep-cut river-bed of the Guadiana, was manganese-ore still found at a depth of 330 feet. About 15 years ago, however, it was discovered that the above-mentioned exhaustion in depth of the manganiferous deposits in reality applied only to the oxides of manganese; but that silicates and carbonates of manganese (in incomparably greater quantity) occur down to considerable depths, in beds and lenticles similar in structure and succession to the pyrites-deposits, and alternating just as these do with the shales. The carbonate and silicate of manganese are undoubtedly primary deposits of sedimentary origin, while the superficially occurring pyrolusite and the associated jasper are secondary deposits—the alteration-products indeed, of the others and in a sense comparable with the ferruginous gossan of the pyrites-deposits. L. L. B.

ARGENTIFEROUS GALENA OF CADLIMO, SWITZERLAND.

Sul Giacimento di Galena argentifera dell' Altopiano di Cadlimo. By E. MARIANI. *Giornale di Geologia pratica*, 1906, *vol. iv., pages* 94-98, *with* 1 *figure in the text.*

The high *alp* or Piatto di Cadlimo, lies among the mountains which form the eastern wing of the St. Gotthard group, in the commune of Quinto, district of Leventina, canton Ticino. The rocks hereabouts consist essentially of gneisses alternating with mica-schists, striking on the whole east and west, and dipping northward at 45 degrees or so. The galena-deposit occurs somewhere about the middle of the area described, and prospecting-work was started on it in the summer of 1904 by an American company, which had obtained a concession from the cantonal authorities. The existence of the deposit had long been known, and more or less spasmodic investigations had been made at various times, but the earlier prospectors were hampered by the lack of means of transport and easy communication with the main valley of the Ticino. The spot lies for a great part of the year buried in snow, and was high up away (until quite recently) from any road that could be regarded as really suitable for wheeled traffic. Now, however, a good road has been made up from the Piora valley to the Piatto di Cadlimo, and temporary dwellings and stores have been constructed for the use of the men who are to open up the mine.

The author visited the spot in September, 1905, under the auspices o the engineer-in-charge, and had the opportunity of examining a great dea of material which had been brought to bank in the course of the recen exploration-work. The gneiss-and-mica-schist complex is hereabouts traverse by a number of fissures generally striking from south to north, and narrow ing somewhat near the surface; some of them pitch steeply westward, other eastward, and yet others are vertical. The argentiferous galena, irregu larly intermingled with gangue, fills up these fissures. The gangue appear to be made up of highly decomposed fragments of the country-rock, with a argillaceous film. The galena occurs in splendidly lustrous masses showing well the cubic cleavage, and also in "granular masses," really made up of big nodules, consisting, in concentric alternation, of bands of galena, mica, and quartz. Various chemical analyses show that the percentage of metallic lead in the ore exceeds 77·65, while the amount of silver varies from 7·78 to 10·25 ounces per ton; but the author considers that a much greater number of samples must be subjected to analysis, before it will be possible to form a definite idea of the exact industrial value of the deposit. The galena is also dispersed through the very smallest cracks that radiate from the prin cipal fissures, in such wise that the country-rock at many places appears to be impregnated with the ore. As the veins of galena crop out at many distinct points, and remain for some distance parallel one with the other, the idea suggests itself that they converge in depth into one great ore-body. At an altitude of 8,364 feet above sea-level, mining operations will hardly prove possible throughout the year, and yet the author thinks that work may go on there during as many as 300 days out of the 365. L. L. B.

MINERAL-RESOURCES OF ASIA MINOR.

(1) *Die Gewinnung nutzbarer Mineralien in Kleinasien während des Alterthums.* By Fr. Freise. *Zeitschrift für praktische Geologie*, 1906, *vol. xiv., pages* 277-284.

The colonies founded in Asia Minor by the ancient civilized peoples of Egypt and Asia were essentially mining colonies, and so the mineral-industry (including metallurgy), even in very remote ages, attained a high degree of prosperity in the Levant. Two points are worth bearing in mind: (1) that the total quantity of metal in use in those days was infinitesimally small, in comparison with that required by the necessities of modern civilization, and consequently mines and smelting-works were conducted on a correspondingly smaller scale; (2) that metals had a far higher value in relation to manual labour (then mostly slave-labour) than nowadays. Thus it was possible in ancient times to mine at a profit deposits which would now be absolutely unworkable, despite the enormous progress that has meanwhile been made in all the technicalities of mining: since metals are lower, and manual labour is higher, in value. This consideration should weigh with the modern prospector, when he suggests the resumption of mining operations on deposits which were formerly remunerative.

The ancients, in hewing out the ores of which they could make use, left calamine and zinc-blende severely alone, as they were unfamiliar with the methods of extracting zinc, especially from the latter ore. The mineral-industry, flourishing under the Lydian kings, the Romans, and the Byzantine emperors, rapidly declined after the Osmanli conquest, and remained in a state of paralysis for five centuries, with the exception of the silver-ore mining carried on at Gümüsh-Khane in northern Asia Minor, and the copper-ore workings of Arghana-Maaden in Kurdistan.

A short general sketch is given of the history of the sub-continent, and then the author enters into details, gleaned from various classical writers, as to the minerals obtained and worked in Phrygia, Mysia, Lydia, Caria, and Lycia (forming now the vilayets of Khodawendikjar and Aidin). Thereafter he glances at the islands lying off the western coast: Lemnos, Lesbos, Samos, and Rhodes; and then at the region which practically constitutes the vilayet of Konia—the ancient Pisidia, Pamphylia, Lycaonia, and Cilicia, completing his survey of Asia Minor with the northern portion thereof, including Bithynia, Paphlagonia, Pontus, Cappadocia, and Galatia. He regards Cyprus and Crete as coming geographically within his purview, and notes that the copper-ores of the former island originated the very name of the metal (*cyprium, cuprum*) in all civilized languages.

(2) *Bodenschätze und Bergbau Kleinasiens.* *By* C. SCHMEISSER. *Zeitschrift für praktische Geologie*, 1906, *vol. xiv., pages* 186-196, *with a map in the text.*

Geological investigations in Asia Minor have hardly been pushed far enough as yet, to permit of an accurate general view of the subject. It is sufficient for the present to state that samples of the formations of all ages, from the Archæan down to the most recent, are of more or less extensive occurrence, but that next to the great crystalline mass (Prof. A. Philippson's Lydian massif) of the central region, Tertiary deposits predominate overwhelmingly. Relying for a geographical and geological description of Asia Minor on one or two lengthy quotations from Prof. Philippson, the author gives details of the occurrence of useful minerals in the following order:—

Meerschaum is found in a soft tufaceous brecciiform rock, grey to reddish-brown, at the base of the serpentine-hills which rise south and south-east of Mount Olympus in the vilayet of Brussa. The mineral is probably an alteration-product of the magnesite which forms a complex network of veins in the serpentine. In place the meerschaum is grey, soapy, and very soft, but soon hardens after its extraction (in lumps of the size of about an apple) from the matrix, and becomes paler in colour. The meerschaum-deposits lie east of Eskishehir in the Pursak valley, where near the river they attain a maximum thickness of 233 feet, thinning away towards the hills, and finally nipping-out altogether. Within an area of barely 2 miles in diameter in that valley, as many as 4,000 shafts have been sunk; but the method of working is far from economic, as mining operations are conducted by a great number of lessees, each employing a very few men. The lessees pay a tax of 15 per cent. to the Ottoman Government, the annual output of 150 tons or so having been for many years exported in its entirety to Vienna.

Pandermite, a borate of lime nearly related to borax, has received its name from the shipping harbour of Panderma on the Sea of Marmora. The best-known deposit of the mineral occurs some 43 miles south of the sea-coast and 18½ miles north-east of Balikesri, at Sultanchaïr, in the form of dazzling white masses, varying in size from a pin's head up to blocks weighing ½ ton or so, within a bed of gypsiferous clay, some 115 feet thick. The mineral appears to be of volcanic origin, and to have been brought by means of springs into an extensive lake-basin. American competition has proved, of late, highly detrimental: the output, which at one time averaged 200 tons of 25 to 30 per cent. pandermite daily, sank in 1903 to 6,000 tons for the whole year. The price, too, has gone down to such an extent that the profits of working the Sultanchaïr mines average barely 5 per cent.

Salt is evaporated from rich brines at Giabul in the vilayet of Aleppo, and from saltings at various points along the sea-coast. It is also got from the great salt-lake of Tutz-Chöllü in Lycaonia. Rock-salt-deposits, 130 feet

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or more in thickness, are worked at Tutz-Kiöi, near Nevshehir, and three other localities where the same mineral is worked are mentioned.

Of the numerous deposits of emery, more especially abundant in the vilayet of Smyrna, comparatively few are being worked at present. The mineral usually occurs as a secondary deposit in a brecciated form in a reddish-brown earth, or intermingled with fragments of limestone embedded in earthy limestone in far-stretching cavities or fissures among the crystalline limestones. The greatest known cavernous deposit of this nature is about 330 feet long, 66 feet wide, and 33 feet high. The mineral is worked both opencast and underground, and the crude material is sorted by hand: the percentage of corundum therein varies between 40 and 57. The annual output ranges from 17,000 to 20,000 tons, and is mostly absorbed by Great Britain, the United States, and Germany.

Chrome-iron-ore is the most important iron-ore that Asia Minor can show: it is said to exist there in quantity sufficient to supply the world's markets for generations to come. The known deposits may be grouped in three well-defined areas: (1) the north-western, in the province of Brussa, in the vicinity of Mount Olympus; (2) the south-western, including the districts of Denizly and Makry, and the shores of the Gulf of Adalia; and (3) the south-eastern, around the Gulf of Alexandretta, in the district of the same name and in that of Adana. Careful prospecting will no doubt reveal in time further deposits of the ore in the remoter provinces. In the region of Brussa, the chromite is, like the meerschaum, associated with serpentine as its original matrix. It occurs irregularly therein in the form of flattish lenticles, stringers, pockets, etc., often traversed by faults; more than 120 such occurrences have been recorded, among them that of Daghhardy, 12½ miles south of Chardy, said to be the biggest and richest of the kind in the whole world. Here about 10 million tons of ore, containing from 51 to 55 per cent. of chromic oxide, are in sight. The export of chrome-iron-ore from Asia Minor has in recent years amounted to 40,000 tons per annum, and the output up till the year 1903, at any rate, equalled that of all other countries taken together; but New Caledonia is proving a formidable competitor.

Iron- and manganese-ores are doubtless of widespread occurrence in Asia Minor, but the economic conditions are such that few of them can be worked at present, and those chiefly perhaps in the vilayet of Smyrna. At Rasheya in Syria, north of Mount Hermon, the working of the iron-ore-deposits is facilitated by the occurrence at the same locality of seams of lignite. Cinnabar and gold and silver-ores have been found, again in the richly-mineralized vilayet of Smyrna.

In Asia Minor, the oft-repeated axiom that plumbiferous ores need to be argentiferous as well, in order to repay working, holds good once more. The lead ores are more especially found in those districts where eruptive rocks have invaded the sedimentary deposits. Three such areas are distinguishable; the eastern, western, and southern. To the first-named belong about 15 deposits between Zara and Karahissar in the vilayet of Sivas; to the second the great mines of Balia and Menteshderé; and to the last-named the great Government mines on the southern flank of the Bulgar-Dagh, besides many other localities enumerated by the author.

The copper-ores are conveniently grouped in a north-eastern and a south-western area, whereof the latter is of far less importance than the former. First and foremost in the north-eastern area may be mentioned the mines of Arghana Madén, between Kharput and Diarbekir, not far from the Lake of Giöldjik where the Tigris takes its rise: Naumann's description of them

is quoted, and the author adds that the mines are most wastefully worked by a number of small capitalists, who farm them from the Turkish Government. It seems possible that the authorities will refuse to allow this to continue much longer, and that a chance will be given to syndicates powerfully backed by a sufficiency of capital to conduct operations economically on a large scale. The one drawback is the scarcity of fuel. The hinterland of Trebizonde and Sinope respectively, is also rich in copper-ores. The south-western group includes the mines of Bulbuderé, Assarli, and Cos in the vilayet of Smyrna, and the apparently rich deposits of Tokad and Kalabak, near Balikesri. The total output of Turkish copper-ores for the year 1902 amounted to 1,118 tons.

Antimony-ores occur in the vilayets of Brussa, Smyrna, and Sivas, and are in part worked, but the statistics of output, etc., are said to be exceptionally unreliable. Arsenical pyrites is largely worked in the vilayet of Smyrna for the sake of the gold which it contains, rather than for the arsenic. Occurrences of calamine, native sulphur, and alum are also enumerated.

The coal-deposits on the shores of the Black Sea are of especial importance for Asia Minor. They extend over a belt of a maximum width of 6½ miles, from Bender Eregli eastward to Amasra. Many of the seams are from 10 to 13 feet thick, they dip as a rule not more than 10 or 12 degrees, and crop out at the surface. They are worked by adits following the dip, until the inflow of water compels the abandonment of these primitive mining operations. The coal is said to be suitable for metallurgical purposes, for coking, and for firing boilers. The Turkish Government works that portion of the coal-field which lies within the Imperial domain, for the supply of the fleet and the arsenals, and if the authorities could only bring themselves to lease the remainder to syndicates prepared to work the coal by the most approved modern methods, an immense development of the mineral-industry hereabouts would ensue. Few concessions have been granted up to the present, the most important being that of the Heraklea company, whose output for the year 1900 amounted to 255,000 tons. The new harbour of Songuldac is being built for shipping the coal. About 35 or 40 miles north-west of Erzerum, a very sandy impure coal is worked by means of adits, but the quality may be found to improve in depth. Other occurrences are cited, which lead to the inference that productive coal-measures extend more or less continuously very nearly to the Persian frontier. At Namrun, 12 hours' camel-ride from Mersina in the province of Adana, coal is being worked by a German lessee.

Brown coal is of widespread occurrence, and as wood-fuel is scarce on the high plateaux, the deposits, where sufficiently rich, should prove of more than local importance. Finally, the author enumerates occurrences of petroleum, asphalt, and bituminous limestones (the Dead-Sea region being extensively cited in connexion with all three), phosphates, fullers' earth, soapstone, lithographic slates, and opal.

There seems to be no question that a systematic geological survey of Asia Minor would vastly extend the known occurrences of useful minerals. The economic and legal conditions of the country are, however, at present so unfavourable, that nothing short of revolutionary changes can effect the complete utilization of its mineral resources. As might be expected from a writer of the author's nationality, due stress is laid on the importance of the Baghdad railway as a new factor which makes for progress. Moreover, the Anatolian Railway Company have been authorized to work any mineral-deposits which they may discover for 12½ miles on either side of the Baghdad line.

L. L. B.

Iron-ores occur throughout the productive coa
of the thin bands previously mentioned, or in lentic
include brown iron-ores as well as sphærosiderite.

GOLD-BEARING REGIONS OF

(1) *Carte géologique de la Région Aurifère de la Zéia:*
2 *et III.* 3. *By* E. AHNERT. *Explorations*
Aurifères de la Sibérie, 1904-1906, *pages* 1-304 *a*
(2) *Région Aurifère de la Léna. By* A. GERASIMOFF *a*
Ibid., livraison iii., pages 1-43 *and* 45-60, *and* 2
(3) *Région Aurifère de l'Amour. By* E. AHNERT, M.
P. RIPPAS *and* P. YAVOROVSKY. *Ibid., liv*
5 *maps; and*
(4) *Carte géologique de la Région Aurifère de l'Amour:*
Feuille I. By A. KHLAPONIN. *Ibid., pages* 1-7

The area dealt with in the two memoirs includ
126° 6′ to 127° 6′ longitude east of Greenwic
55° 20′ latitude north. It is watered by three
Olongro, and the Dess) belonging to the Brianta
still smaller streams belonging to the Ghilui rive
undulating, and is traversed near the western lin
from north to south by a mountain-range. Along
and in their vicinity, high scarps, wild ravines, a
the rugged character of the surface-relief in the w
There are, too, marked belts of depression; and,
graphical features are undoubtedly the result of
erosion, tectonic agencies have also played their
features. The predominant rocks are of granitic ty
clase-granite (prevalent in the eastern and less rugge
pale biotite-granite; also plagioclase- and quar
of extremely varied composition, trachyte-andesites,
peridotite. The gneisses occur in great variety, i
matitic gneisses, at least two biotite-gneisses,
The gneissic rocks are of typically secondary formati
originating from massive crystalline rocks which
plicated process of multiple injection of eruptives al
age-planes, coupled with recrystallization of their
ence of partial solution and great pressure.

The sole undoubted sedimentary deposits in t
of rubble resulting from the superficial weathering
drift, and alluvia; the hill-slopes are mantled by
the maximum thickness of which is usually depen
perpetually frozen ground (20 to 40 inches, accordi
Gold-bearing solid rocks have been sought for in
washings are occasionally conducted in the sands of
The author himself found traces of gold on experi
in the gorge of that river; but the alluvia of the
are barren. Quartz-veins of any consequence have
in the scarps abutting on all these valleys. Che
to yield traces of gold in any rocks from the distri
gneiss and spidotic mica-gneiss, and the porphyrite,
The singular absence of pyrites in all these rocks
exception of the Unakha granites.

The investigations of Mr. A. Gerasimoff were continued in 1902 in the Olekma division of the Lena region, a rugged country made up of metamorphic rocks (schists, phyllites, grits, and quartzites) and sedimentaries (limestones, dolomites, mottled gypsiferous clays, etc.) of probably Cambrian age. Recent alluvia are found only along the Lena, and the gold-mining industry is of scant importance. The Mikhailo-Ivanovsky workings in the Vacha basin are no better organized than the chance diggings of clandestine prowlers after gold, and yield barely 650 grains of the precious metal per ton of material. The Spektralny mine, worked both opencast and by underground galleries, yields 1,234 to 1,390 grains of gold per ton of material. The Voskressensky placer is exhausted.

Mr. Preobrazhensky explored the Takhtyga and Anangra river-basins, immediately to the west of the region just described. It is an extremely rugged country, the valleys being oriented in every possible direction, in disregard of the strike of the rocks. These valleys are in the form of broad marshy troughs in their upper portions, narrow (though occasionally widening into lakes) in their lower portions. One half of the area is taken up by granites, the other half by schistose metamorphic rocks. Gold certainly occurs in the alluvial deposits—there are, however, few outcrops of these, and they have not been minutely studied as yet. In the two river-basins there are in all five placer-workings, and those not very actively worked. The gold is distributed so irregularly in the sands, which are themselves so inconstant, that the district has acquired an unfavourable reputation from the point of view of the gold-mining industry—the more so that exploration-work had been of a very inadequate description. However, the barren cover is of no excessive thickness (from 13 to 33 feet), and all the geological data concur in assigning to the sands a sufficient quantity of the precious mineral to justify mining operations which would most probably be remunerative.

Turning now to the Amur region, we find in Mr. Ahnert's description of his traverses of the Stanovoi mountain-range and of the Zeia and Aldan basins between which it forms the water-parting, that in 1902 four placers were being worked in the so-called "Aldan gold-belt," and that requests for concessions had been put before the Government authorities to work every watercourse in that area down to the smallest streamlet. But little exploration-work had been done, except in the case of the placers just mentioned. The amount of gold in these placers depends directly on the nature of the rock which forms the subsoil in the respective localities. There is reason to believe that in no case has the gold been transported by water for any considerable distance.

Researches in the region of the Amgûn (a left-bank tributary of the Amur) tend to show that along its lower course the presence of gold is in some way connected with the crystalline schists; while along the Kolchan (a tributary of the Kol which flows into the Sea of Okhotsk), the precious metal appears to be connected with the most recent eruptive rocks, especially the liparites.

The gold-bearing portion of the Little Khingan district is made up almost entirely of gneisses and granites and crystalline schists, the geological conditions being much the same as in other gneisso-granitic regions of the Amur basin. The primary matrix of the gold appears to be predominantly the dark gneiss, and also the dyke-rocks of the granitic group (pegmatite and tourmaline-granite). Segregations of hornblende are good indicators, while the quartz-veins which occasionally seam the gneisses are comparatively poor in gold. All the placers in the area here described are of post-Pliocene age, except the Nagorny placer, which lies 260 feet and more above the level

of the Sutar river. Here, the sands, resting upon granite, include an auriferous layer from 30 inches to less barren "cover" varying in thickness from 33 to of this "cover," as much as 15½ grains of gold p auriferous layer proper yields anything between 3 the average yield of that portion of the placer w 1901 exceeding 46 grains per ton. The post-Pliocc or redeposited (*remaniés*), are hardly conspicuous fo normal tenour not exceeding 38½ to 115¾ grains pe occasionally reaches a maximum of 185 grains per t

In the Jalinda region west of the Amur, gold exist; but no practical results have yet been achiev the alluvial gold alone is worked. The placers are the entire area, in groups of small extent; some derived from the dyke-rocks (pegmatites and apli of contact-metamorphism at the junction of the sedi granitic rocks, while others again are genetically a ose conglomerates and grits.

Mr. A. Khlaponin, in describing the geology of the primary origin of the gold in the placers to and points out that, more especially in the western of dislocation and erosion have assumed greatest may expect to find auriferous sands rich enough to

(5) *Die Goldseifen des Amgun-Gebietes (Ostsibirische* MAIER. *Zeitschrift für praktische Geologie*, 19 *with* 11 *figures in the text.*

In the great belt of auriferous deposits which Siberia from Transbaikalia onwards, those which li most recent origin belong to the gold-placer group district is topographically defined on the east by t ing northward from Khabarovsk through the region Chikchagir, etc.), and on the west by the mountain gan. The Amgun itself is a left-bank tributary, of the great river Amur, into which it debouches al ayevsk. In its middle course it flows through t while its more important left-bank tributaries (am the Nilan) take their rise in the northern spurs of is more particularly in the area defined by the Ker gold-placers presently to be described are situate extends through seven degrees of latitude north Okhotsk, and is built up of a great variety of rock tives are chiefly represented by a granite-porphyry mountains, from altitudes of 3,500 to 4,000 feet or to a height of 6,400 feet. From its eastern bas proper stretches eastward, in the form of a well-w which has rather the character of a succession of f to the Amgun-Amur plain. The Kerbi and the are distinguished by their length, and by the volu alluvial deposits, from all other rivers in that region débris, while the rivers which intervene between th their erosive activity to areas of crystalline schi true that north of the lower course of the Kerbi, which is the sole auriferous deposit that cannot

South-east of the auriferous district great masses of granitic rocks apparently occur between the upper course of the Amgun and the Amur, and it would seem that we are dealing with an area of gold-bearing slates ringed round by granite. Quartz is of widespread occurrence, and is seen in the few available natural exposures to take the form of lenticles and nests; consequently, it furnishes much of the material of the alluvial deposits. Pyrites is also a very commonly-occurring mineral in the slates.

The working of the gold-placers was started in 1882 in the upper valley of the Sulaki, a right-bank tributary of the Kerbi; but the industry only began to attain real importance in the early nineties, on the discovery of the placers along the Semi and Sulatkitkan rivers, which have since then furnished by far the largest portion of the entire gold-output of the region. The official statistics put the production of the Amgun district for the period 1891-1904 as totalling 739,450 ounces troy, but to this should be added the considerable percentage stolen by the workpeople. The stolen gold was mostly squandered on smuggled spirituous liquors (a strictly forbidden traffic), and by secret and devious routes found its way into China. But, of late years, the Russian Government have put an end to the temptation to smuggle by proclaiming free trade in gold; and the most important mining company in the district having largely replaced manual labour by excavating machinery, the secret pilfering of the precious metal has become exceedingly difficult.

The author appends a map showing the distribution of the workable placers, but refrains from indicating those which are still merely in the prospecting stage. He finds himself able to state, however, that there is little hope of discovering in the district any more placers as rich as those of the Semi and the Sulatkitkan. Apart from the centre formed by these two rivers, the distribution of the workable placers is irregular in the extreme; but traces of gold are everywhere discernible in the alluvial deposits of every valley in the district without exception. One rule, however, can be stated in regard to the workable placers: they are not known to occur in valleys where the stream has a greater fall than 4 per cent., and the most considerable auriferous deposits are found in valleys where the fall ranges from 1 to as little as 0·5 per cent. The valleys are almost invariably asymmetrical, one side being much steeper than the other; and the breadth of the thalweg is generally considerable, an indication of extraordinarily active erosion. An essential characteristic of the alluvial deposits is, that the material of which they are composed is identical with that of the bed-rock and of the rocks now cropping out in the hillsides. Hence the primary source of the gold that occurs in the placers may be looked for in those very rocks.

A detailed description (with map and sections) is given of the placers of the Semi valley and its tributaries, the workable deposits extending over a total length of 12½ miles or more, while the breadth is found to increase progressively as one goes down stream. The climatic conditions recall those of the Klondyke region, but there is at present no adequate evidence of a former complete glaciation of the district. The most important auriferous horizons in the placers are the weathered surface-débris of the phyllites (not immediately above the bed-rock) and the overlying lowermost gravels; but gold does occur more or less abundantly at every horizon, diminishing from bottom to top, with the above-mentioned reservation. A certain amount of gold occurs, occasionally in rich nests, among the bedding-planes of the bed-rock itself, but so irregularly that the working of it is generally leased out to Chinamen and Koreans, whose primitive methods of mining can alone make the stuff payable. An indicator of the presence of gold in the alluvia, etc.,

in fact, the sole visible indicator, is the peculiar clayey "cement" known to the Russians as *primazka*, which coats the pebbles and rock-débris, fills up depressions and fissures, and often forms the binding-material of the detrital deposits. But, although the gold practically never occurs without the *primazka*, the latter is sometimes found without any gold. An elaborate table is given exemplifying the vertical distribution of the precious metal; and the erosion of the Semi valley, as also the accumulation of its gold-bearing alluvia, is attributed solely to the agency of running water. The author states that practically all the placers of the Amgun district are similar in character and origin to those of the Semi; the material of which they are built up is exclusively derived from the phyllites and the crystalline schists. The exception already hinted at, in the case of the Kerbi and Nilan rivers, must, however, be borne in mind: here the alluvia of more recent date are formed of granitic débris derived from the granite-ridges of the Little Khingan. Little exploration-work having been so far accomplished along the Nilan, the author is perforce restricted to a description of the Kerbi placers. Now, although the Kerbi flows for many a mile through a region of slates and schists, and only its headwaters are in the granitic area, the mountains slope so abruptly, the rains are so heavy, and the variations of temperature so enormous, as to intensify erosion to such an extent that the granitic material plays the most important part in the detrital deposits along the entire course of the river. Nevertheless, the gold which occurs in the Kerbi placers is in every respect similar to that of the Semi, and is evidently derived from the schist-and-slate complex. The Yassnyi placer alone, on a tributary which runs into the Kerbi from the north, contains gold derived from the granites, easily distinguishable from the slate-derived gold by its fine even granularity and its crystalline form. A series of great terraces of older alluvium marks out in some places the ancient course of the Kerbi, and in these also gold occurs. The probable history of the formation of the placers is sketched out, and some typical examples are described.

As to the quantity of gold which they contain, this is variable in the extreme, ranging from mere traces to an ounce, or occasionally over 3 ounces troy per metric ton. The average output per ton washed has diminished of late years, but this is (to a great extent) attributable to the fact that, by the modern methods of mining now in vogue in the Amgun district, the poorer stuff is washed as well as the richer. The total output is therefore increased, although the averages have decreased. The workability of a placer hereabouts does not, moreover, depend so much on its absolute wealth, as on the relative thickness of the barren "cover." The gold of the upper tributaries of the Kerbi (Sulaki) and the Nilan (Sivak) is characterized by its coarseness of grain; nuggets weighing from 15 to 150 grains (1 to 10 grammes) are common in all the placers, and some weighing from ½ to 2 ounces (10 to 60 grammes) are occasionally found, but in certain placers only. Once a nugget weighing over 25½ ounces was discovered. The precious metal is generally irregular in form, but in several placers crystals that have undergone very little water-rolling occur, and larger fragments are made up of crystals, or exhibit a symmetrical structure reminiscent of skeleton-crystals. Quartz is frequently associated with the gold, and other mineral-associates are pyrites, magnetite, specular iron-ore, brown hæmatite (forming a film on the gold-flakes), stibnite, and very rarely garnet. In regard to its chemical composition, the gold varies from 910 to 952 fine, the impurities consisting chiefly of silver with a little copper.

The evidence is detailed, by which the author is led to the conclusion

that the entire complex of phyllites and metamorphic schists of the Amgun district, together with the quartz and pyrites which they contain, forms the primary matrix or mother-rock of the gold. Whatever chemical processes may have taken place within that matrix before its erosion, it is certain that, dating from the erosion, the formation of the placers was originated by purely mechanical processes.

The eternally frozen layer in the subsoil of the district (below the 5 feet or so of surface-soil which freezes hard every winter and thaws again in the summer) is of curiously irregular distribution, and does not seem to affect one way or the other the general regularity of the placers. L. L. B.

MINERAL RESOURCES OF THE CHUKCHEN PENINSULA, EASTERN SIBERIA.

Tschuktschenhalbinsel (Ostasien). By J. KORSUCHIN. *Zeitschrift für praktische Geologie*, 1906, *vol. xiv., pages* 377-382, *with* 2 *maps in the text.*

When the world-renowned gold-placers at Cape Nome, on the Seward peninsula, were discovered in 1899, it occurred to certain enterprising Russians that there was a possibility of finding similar wealth in the soil of the Chukchen peninsula, which faces Cape Nome on the opposite side of Bering Straits. The exclusive right to search for gold and other useful minerals over the entire peninsula, in other words, over an area of 38,601 square miles, was conceded to Mr. W. von Wonliarliarsky, who thereupon sent out several exploring expeditions in succession to that remote region. The author was the leader of the expedition that went out in the year 1903, since when (he believes) no further investigations have been carried out in the Chukchen peninsula. Although it had been discovered as long ago as 1648, the interior of the country remained practically unknown as late as the year 1900, when Prof. Bogdanovich led thither the first Wonliarliarsky expedition. During the short Arctic summer the professor devoted his attention to the geological survey of the coast, but scientific work was much hindered, and finally stopped, by the bickerings which arose among the members of the expedition. A synopsis is given of such petrographical and geological data as, under these difficulties, Prof. Bogdanovich was able to accumulate.

In Abolesheff Bay, he found lodes of pyrites traversing felsite-porphyries, and that the shores of Providence or Plover Bay consist exclusively of crystalline igneous rocks, among which biotite-granite plays the chief part. Limestones, mica-schists, calc-schists, and talcose schists occur between Cape Pageliau and Koniam Bay, on the northern shore of which they are overlain by eruptive rocks, chiefly granites and porphyries; fine-grained, pale-grey sandstones were observed in Mechigmen Bay, and the headland of Cape Dezhneff, which juts out into Bering Straits, is built up in part of limestone and in part of hornblende-granite.

In the beginning of July, 1903, the steamer carrying the expedition under the author's command, dropped anchor in Lawrence Bay, in the north-eastern portion of the Chukchen peninsula, 21 days after leaving Vladivostok. On the shores of the above-mentioned bay is a trading-station belonging to the company founded by Mr. W. von Wonliarliarsky. The author utilized the week during which the expedition was inevitably delayed there to examine the north-western coast, where it was reported that, shortly before his arrival, certain American prospectors had struck auriferous deposits. This statement, however, appears open to doubt, as the so-called ore-deposits proved to be very irregular aggregates of quartz containing chalcopyrite and iron-

pyrites, at the contact of hornblende-granite with on the spot for assaying the quartz being available samples away with him; but these were lost when on the return journey, on the coast of northern Japan.

The peninsula is bare of woodlands or even of tions are obliged to carry their fuel with them, in Despite these and many other difficulties, the author geological map of the north-eastern portion of the pe of which are covered by granites and gneisses; there stone and some clay-slates. The importance of last-named lay therein, that the occurrence of gold on the American side of the Straits, is connected clay-slates or shales. The author reports, in regard he found along the course of the Kolöl river, that and, so to say, intergrown with ice, which never th are overlain by a few feet of loamy rubble, and seam At one locality only were signs apparent of a qu thickness, and this does seem to be auriferous. O but very slight traces of gold in the clay-slate area.

South-west of Cape Dezhneff, there is a gold-p not far from the trading-station at the mouth of th is a highly-contorted, much metamorphosed clay-s into mica-schist, and is traversed by a multitude placer only yields about 7 grains of gold per ton, s industrial importance.

The author discovered a graphite-deposit on th hill, near the headwaters of the river of the same of extraordinarily fine quality, and is compared wit of Ceylon graphite. It occurs in big lenticles, in a striking north-westward and dipping almost at ri traced this belt for a distance of 1¼ miles; he estima at the very least 70 to 100 feet; and reckons the avera in the gneiss as ranging from 15 to 20 per cent. N deposit, the author came upon a large patch of gr of brown hæmatite, which would seem to indicate th of iron-ore; but he was deprived of the opportunity the matter.

The author is inclined to correlate the rocks of coast of the Chukchen peninsula with the oldest rocks classified by the American geologists as the Kigl granted, Bering Straits would represent a sunken tween the second anticline of the Seward peninsu on the Chukchen peninsula, and there are reasons for tion of the two peninsulas by the sea took place i The conclusion is reached that the recurrence of gold-bearing rocks of the Nome Group must be loc of Koliutshin Bay and Anadyr Bay on the coasts of It is noticeable that on the Seward peninsula, all the coast, such as Norton Bay, Port Clarence, Eschs with the development of this Nome Group.

COPPER, TIN AND GOLD IN KATANGA, CONGO FREE STATE.

(1) *Les Gisements de Cuivre du Katanga.* *By* H. BUTTGENBACH. *Annales de la Société géologique de Belgique*, 1905, *vol. xxxi., Mémoires, pages* 515-564, *with* 10 *figures in the text and* 1 *plate.*

The Katanga district, properly so-called, lies in the extreme south-east of the Congo State, between the tenth degree of latitude south and the water-parting of the Congo and Zambesi river-basins. It had long been known as the source whence the natives of the neighbouring regions derived the copper from which they made their implements and utensils, and was traversed by various explorers in the latter half of the nineteenth century. It was not, however, until 1885 that a European actually examined one of the cupriferous deposits. In 1902, the author was commissioned to carry out investigations in the district, by a Belgian company which was working in agreement with the Tanganyika Concessions, Limited, and the result of 18 months' prospecting-work more than confirmed all the expectations that had been formed. In a word, the Katanga district may be regarded as one of the richest (if not itself the richest) copper-ore fields in the whole world. And yet exploration-work was not pushed to a vertical depth greater than 130 feet or so, because the ore-deposits proved to be so numerous and so extensive that (for the purpose in view) it was not considered needful to do so. The deposits are very similar in character, and a detailed description of each one would involve a monotonous repetition, varied only by statistics as to area, etc.

The country, as a whole, is a vast undulating tableland, comparable in some respects with the plateau of the Ardennes, varying in altitude from 4,300 to 4,600 feet, but with some elevations going up to 5,300 feet. The rivers, which have, in a few cases, cut very deep gorges in this peneplain, are divisible into two main systems: (1) the south-to-north flowing rivers, including the Lufira, the Lualaba, and their principal tributaries; and (2) the lesser tributaries of the foregoing, which flow in a direction sensibly at right-angles to that above-mentioned. No eruptive or granitic rocks occur within the mining district itself; the strata are all sedimentary, sometimes intensely metamorphosed, and generally dipping at an angle higher than 45 degrees. Towards the north these beds are overlain by practically horizontal grits, which are possibly of lacustrine origin. In the mining district, the Kazembe and Kafunda-Mikopo systems of Prof. J. Cornet (Upper Devonian and doubtfully Carboniferous) are chiefly represented, the predominant rocks being the Upper Kazembe violet schists. The author indicates on his map no less than sixty-six distinct cupriferous deposits, but there are many other localities where strata impregnated with malachite are known to crop out. The ore-deposits almost invariably occur on the slopes, or on the brows, of more or less isolated eminences, the barren aspect of which contrasts vividly with the luxuriant forest amid which they uplift their crests. The copper-salts with which the soil of these hills is saturated probably account for their sterility. The ore (malachite and chrysocolla) appears to have been precipitated amid all the fissures and interstices of the strata by metalliferous solutions which percolated through them. The bands of malachite, even at Kakanda, whence show-specimens are obtained, hardly ever exceed 2 inches in thickness. The malachite is frequently mammillated, and, in such cases, alternates with chrysocolla. The average results of assays of ores selected from ten different deposits show a percentage of 14·21 of metallic copper. Gold and silver are always present in varying proportions, as is proved by the analysis of more than 150 samples: in some cases the amount of gold exceeds 45 grains per

ton, and that of silver 2½ ounces troy. Pulverulent intermixed with oxides of iron and manganese, is rence in the Katanga deposits, and is probably deri tion of other minerals. Chalcopyrite and cuprite native copper has been found, in rounded grains, of which is formed by the tailings washed down fr the Kambove deposit.

For description, the author selects those deposi to be of the greatest importance or interest. So Fungurume, Luushia, Kolwezi, and Kambove deposi last-named deposit has been the object of a good d but the shafts have hardly been pushed deep enough idea of the enormous industrial importance which the destined to assume. On the whole, the author is incl carbonated ores are merely the oxidized gossan of dee which latter possibly are interbedded with strata o among which the former occur. The wealth of these by his estimate that, in nine localities alone, 1,200,0 be extracted from them.

(2) *La Cassitérite du Katanga.* *By* H. Buttgenbach *géologique de Belgique*, 1906, *vol. xxxiii., Mém figures in the text.*

Within the last year, a belt of stanniferous dep portance has been traced in Katanga, ranging par *graben* (or fault-valley) and its thermal springs, an These deposits would appear to have been formed duri dislocation which determined the course taken by issues from the gorges of Zilo, especially after its con The author has in preparation a geological account future industrial prosperity of which is undoubted; with the description of sundry specimens of cassiterit draws attention to the massif of pegmatoid granite, belt of highland, but extending over a distance appr eastward from the above-mentioned confluences of the On the western flank of this massif tourmaline-quar crop out, and it is at the contact of these rocks (more with the granite that the tinstone occurs in practi is to the south of this district, upstream from th cupriferous deposits occur, as also the auriferous d north-western margin of the Kazembe plain. The the level of the Lualaba more than 1,300 feet down in rush tumultuously over a succession of quartzites, s invaded in places by eruptive rocks.

The stanniferous area is very rugged, seamed lodes occasionally crop out. Usually, however, th gravelly débris of the subsoil, including pebbles of as nodules of tinstone varying in weight from less pounds. These placer or gossan-deposits are not sel value than the lodes themselves.

Geologically speaking, the Katanga stanniferous from those of other regions. In the lodes the cassite with quartz a rock of coarse structure, often cemen

quartz appears to have moulded itself on the cassiterite. The "nodules" of the ore in the soil-débris are generally broken, but they still retain roughly the external form of the original crystals. They present this peculiarity, that the faces of the pyramid, which generally surmounts the quadratic prism of the mineral, are conspicuous both for size and frequent occurrence, and seem to have resisted best the agents of disintegration.

(3) *Quelques Faits à propos de la Formation des Pépites d'Or: Les venues métallifères du Katanga.* By H. BUTTGENBACH. *Annales de la Société géologique de Belgique*, 1906, *vol. xxxiii., Mémoires, pages* 53-70, *with* 5 *figures in the text.*

This memoir is largely based on the investigations which the author has conducted within the past few years in the Katanga district of the Congo Free State. Premising that in Venezuela, according to Prof. A. de Lapparent, the deposits of native gold are probably the ferruginous gossans of lodes of auriferous pyrites; and further, that the size of the nuggets in the Californian gold-placers irresistibly impels the inference that the former outcrops of the lodes, long ago swept away by erosive agencies, were by far richer in gold than the deeper-lying portions, the author proceeds to show how the argument is clinched by the evidence collected in Katanga. There is reason to believe that the nuggets actually increased in size while the gossans were in process of denudation, and while the placers were in process of formation; nor was this growth otherwise than fairly rapid. A sketch-map shows how widespread is the occurrence of gold in the river-sands of Katanga, and how widespread also are the cupriferous deposits, in which gold almost invariably occurs, though in small proportion.

The only important placers thus far investigated are those of Ruwe and Kambove, especially the former. At Kambove it is noticeable (1) that in the ravines, the heads of which lie in a direction opposite to that of the cupriferous deposits, no gold is to be found; (2) that in the Livingstone ravine, where auriferous gravels, extending over a length of 2 miles or more, are worked, no gold occurs up stream of the cupriferous deposit; (3) that outside the ravines, gold is only found on the plateau down stream of the cupriferous deposit and drained by the ravines; (4) that the biggest nuggets occur in the Livingstone ravine, which cuts clean across the cupriferous belt; and (5) that when the gravel is washed in the pan, the quantity of gold obtained is proportional to the abundance of grains of malachite and hæmatite which make their appearance a little before the end of the operation. Now, as, on analysis, the cupriferous grits and shales of Kambove invariably reveal the presence of gold—sometimes as a mere trace, sometimes in such proportions as 15, 30, or 45 grains per ton—it is plain that the placer-gold is derived from those rocks. On the other hand, as the precious metal never occurs in them in the visible shape of nuggets or flakes, it is equally plain that such nuggets or flakes (now found in the placers) must have been formed during the denudation of the former outcrops of the cupriferous deposits. This secondary concentration of gold often takes place (in the tropical regions to which the author refers) with considerable rapidity, and in this connection he cites some almost incredible instances from the Likasi and Fungurume deposits—a single shower in each case having sufficed to concentrate in flakes and nuggets the previously invisible gold. It must not be inferred, however, that all the gold found in the streams of the Katanga district is necessarily derived from the cupriferous deposits. The occurrence of gold quartz-reefs, especially in the south-western portion of the district, is, to say the least, extremely probable.

The author then describes an entirely different order of deposit, that of Ruwe, where gold-nuggets have been formed at the expense of the gold contained in infinitesimally minute particles in a sedimentary rock. On the southern flank of a hill ranging north-east and south-west, a series of friable grits crop out beneath the stratum of surface-débris. They dip 30 degrees north-westward, but flatten out in depth. Near the outcrop they carry thin flakes of gold; in depth, impoverishment unto barrenness is rapid, with the exception of one bed, about 8¼ feet thick, which yields a fairly constant assay of: 11 parts of gold, 12 parts of platinum, and 2 parts of palladium per million. The overlying stratum of surface-débris has been methodically worked for more than a year, and yields gold-nuggets varying in weight from 31 to 2,470 grains (2 to 160 grammes), the average weight being from 154 to 925 grains (10 to 60 grammes). Several of these nuggets are figured by the author.

The Ruwe grits are the result of deposition, in the prehistoric Kazembe lake, of the decomposition-products of the belt of ancient rocks which surrounded that lake, while the surface-stratum is in turn the result of the decomposition of the grits. The nuggets in this stratum are undoubtedly derived from the gold contained in the platino-auriferous bed previously described. They never contain platinum or palladium, which would appear to have remained impervious to the chemical changes that reacted on the gold and silver (the average composition of the nuggets is 99·53 per cent. of gold and 0·47 per cent. of silver).

In the course of his memoir, the author inferentially emphasizes more than once the habit to which gold is subject of concentrating on organic nuclei, but he states clearly that the presence of organic matter is by no means a necessary factor in the process of accretion of nuggets. L. L. B.

BAROMETER, THERMOMETER, ETC., READINGS FOR THE YEAR 1906.

BY PERCY STRZELECKI.

The barometer, thermometer, etc., readings have been supplied by permission of the authorities of Glasgow and Kew Observatories, and give some idea of the variations of atmospheric temperature and pressure in the intervening districts in which mining operations are chiefly carried on in this country.

The barometer at Kew is 34 feet, and at Glasgow is 180 feet, above sea-level. The barometer readings at Glasgow have been reduced to 32 feet above sea-level, by the addition of 0·150 inch to each reading, and the barometrical readings at both observatories are reduced to 32° Fahr.

The statistics of fatal explosions in collieries are obtained from the annual reports of H.M. Inspectors of Mines, and are also printed upon the diagrams (plates xxviii. and xxix.) recording the meteorological observations.

The times recorded are Greenwich mean time, in which midnight equals 0 or 24 hours.

TABLE I.—SUMMARY OF EXPLOSIONS OF FIRE-DAMP OR COAL-DUST IN THE SEVERAL MINES-INSPECTION DISTRICTS DURING 1906.

Mines-inspection Districts.	Fatal Accidents.			Non-fatal Accidents.	
	No.	Deaths.	Injured.	No.	Injured.
Cardiff	2	8	0	4	5
Durham	2	26	2	4	4
Ireland	0	0	0	0	0
Liverpool	0	0	0	0	0
Manchester	0	0	0	0	0
Midland	1	1	0	12	16
Newcastle-upon-Tyne ...	1	4	1	7	7
Scotland, East	3	3	5	20	22
Do. West	2	3	1	43	57
Southern	0	0	0	3	4
Stafford	2	2	1	4	5
Swansea	4	8	8	24	28
Yorkshire	0	0	0	6	9
Totals	17	55	18	127	157

TABLE II.—LIST OF FATAL EXPLOSIONS OF FIRE-DAMP OR COAL-DUST IN COLLIERIES IN THE SEVERAL MINES-INSPECTION DISTRICTS DURING 1906.

1906.	Colliery.	Mines-inspection District.	Deaths.	No. of Persons Injured.
*Dec. 6, 1905, 7·30	Newbattle	Scotland, East ...	1	3
Jan. 5, 6·15	Prestonlinks	Do. ...	1	0
,, 28, 8·30	Polmaise (No. 2 Pit) ...	Scotland, West ...	2	0
Mar. 22, 8·30	Phœnix Glyncorrwg ..	Swansea	1	1
June 1, 16·0	Court Herbert	Do.	5	4
,, 2, 6·45	Glenboig (fire-clay) ...	Scotland, East ...	1	2
Aug. 8, 14·30	Coneygre (No. 120) ...	Stafford	1	0
,, 18, 12·30	Penygraig	Cardiff	2	0
,, 21, 8·30	Lingdale mine	Durham	1	1
Sept. 1, 8·5	Portland (No. 2 Pit) ...	Midland	1	0
,, 8, 7·30	Glangarnant	Swansea	1	3
,, 24, 13·30	Dumbreck (No. 2 Pit) ...	Scotland, West ...	1	1
Oct. 14, 23·40	Wingate Grange	Durham	25	1
Nov. 10, 15·10	Albion	Cardiff	6	0
,, 18, 12·30	Cefnstylle	Swansea	1	0
Dec. 12, 10·30	Parkhall	Stafford	1	1
,, 17, 10·35	Urpeth (Busty Pit) ...	Newcastle-upon-Tyne	4	1
			55	18

*Included in list for 1905 amongst non-fatal accidents; the man died, however, early in 1906.

TABLE III.—LIST OF NON-FATAL EXPLOSIONS OF FIRE-DAMP OR COAL-DUST IN COLLIERIES IN THE SEVERAL MINES-INSPECTION DISTRICTS DURING 1906.

1906.	Colliery.	Mines-inspection District.	No. of Persons Injured.
Jan. 2, 15·0 ...	North Walbottle	Newcastle-upon-Tyne	1
,, 5, 0·30..	Phœnix Glyncorrwg ...	Swansea	1
,, 5, 9·30...	Bowhill (No. 2 Pit) ...	Scotland, West ...	2
,, 12, 1·0 ..	Lochwood (No. 3 Pit) ...	Do. ...	2
,, 14, 11·30...	Walkinshaw (No. 2 Pit) ...	Do. ...	1
,, 15, 5·0 ...	Tarbrax (oil-shale) ...	Scotland, East ...	1
,, 15, 13·0 ...	Carnock (No. 2 Pit) ...	Scotland, West ...	1
,, 18, 9·50...	Victoria (No. 1 Pit) ...	Do. ...	1
,, 18, 17·0 ...	Knowle	Stafford	2
,, 18, 20·40..	Newburgh	Newcastle-upon-Tyne	1
,, 19, 7·30...	Phœnix Glyncorrwg ...	Swansea	1
,, 24, 3·0 ...	Blaenavon (Milfraen Pit)...	Southern	2
,, 25, 2·30...	Closyryn	Swansea	1
,, 28, 7·30...	Dumbreck (No. 2 Pit) ...	Scotland, West ...	2
,, 28, 21·30...	Exhall	Midland	1
Feb. 1, 10·30...	Struther (No. 5 Pit) ...	Scotland, West ...	1
,, 6, 8·30...	Manners	Midland	1
,, 8, 8·10..	Hattonrigg (No. 4 Pit) ...	Scotland, West ...	2
,, 10, 8·0 ...	Stanton (Nadins Pit) ...	Midland	1
,, 10, 8·20...	Pye Hill	Do. ...	1
,, 10, 13·0 ...	Pentre	Cardiff	1
,, 12, 15·0 ...	Gartsherrie (Gartcloss No. 1 Pit)	Scotland, West ..	1
,, 14, 16·0 ..	Rigfoot	Do. ...	2
,, 17, 8·30...	Rosehall (No. 14 Pit)	Do. ...	1

TABLE III.—*Continued.*

1906.	Colliery.	Mines-Inspection District.	No. of Persons Injured.
Feb. 19, 12·45...	Cannock Chase	Stafford	1
„ 25, 23·0 ...	Braidhurst	Scotland, East ...	1
Mar. 5, 15·45...	Carmyle (No. 1 Pit) ...	Scotland, West ...	2
„ 8, 15·0 ...	Brook Drift	Swansea	1
„ 12, 14·30...	Cwmllynfell	Do.	1
„ 16, 6·15...	Springhill	Scotland, West ...	1
„ 19, 7·30...	Furnace Blwm	Cardiff	2
„ 19, 15·0 ...	Shawfield	Scotland, East ...	1
„ 24, 6·30...	Parkhead	Do.	1
„ 24, 7·30...	Clynmil	Cardiff	1
„ 28, 19·30...	Raglan	Do.	1
April 1, 9·30...	Shawfield	Scotland, East ...	1
„ 4, 14·30...	Liverton mine	Durham	1
„ 9, 14·30...	Tareni	Swansea	1
„ 13, 7·30...	Glanmwrwg	Do.	1
„ 19, 13·0 ...	Elsecar Main	Yorkshire	2
„ 20, 13·0 ...	Blaenavon (Milfraen Pit)	Southern	1
„ 25, 11·50...	Helm	Yorkshire	1
„ 27, 8·0 ...	Shawfield	Scotland, East ...	1
„ 27, 13·30...	Lanemark (No. 2 Pit) ...	Scotland, West ...	2
May 1, 6·0 ...	Philpstoun (oil-shale) ...	Scotland, East ...	1
„ 1, 7·45...	Cotes Park	Midland	0
„ 4, 12·30..	Motherwell	Scotland, East ...	1
„ 7, 7·30...	Thankerton (No. 6 Pit) ...	Scotland, West ...	1
„ 11, 14·15...	Merthyr Llantwit ...	Swansea	1
„ 16, 4·0 ...	Crigglestone Main ...	Yorkshire	1
„ 22, 7·30...	Prestongrange	Scotland, East ...	1
„ 22, † ...	Morlais	Swansea	1
„ 25, 20·0 ...	Denington	Yorkshire	1
„ 28, 12·15 ..	Victoria (Bruntcliffe) ...	Do.	3
June 1, 0·30...	Graig Merthyr	Swansea	1
„ 4, 7·30...	Cynon	Do.	1
„ 8, 9·0 ...	Capringstone (No. 7 Pit)	Scotland, West ...	3
„ 11, 19·0 ...	Polmaise (No. 1 Pit) ...	Do.	1
„ 12, 8·30...	Carmyle	Do.	2
„ 13, 11·30...	Loscoe	Midland	4
„ 13, 17·0 ...	Twechar (No. 1 Pit) ...	Scotland, West ...	1
„ 14, 8·30...	Pilsley (No. 1 Pit) ...	Midland	1
„ 20, 7·45...	Onllwyn	Swansea	1
„ 25, 12·30...	Pleasley	Midland	1
„ 27, 4·30...	Seaton Delaval	Newcastle-upon-Tyne	1
„ 27, 6·50...	Victoria (No. 1 Pit) ...	Scotland, West ...	1
„ 27, 12·0 ...	Fergushill (No. 28 Pit) ...	Do.	1
July 3, 12·30...	Glynea	Swansea	1
„ 5, 5·0 ...	Mow Cop	Stafford	1
„ 6, 21·0 ...	North Motherwell ...	Scotland, East ...	1
„ 10, 22·0 ...	Do. ...	Do.	1
„ 14, 10·45...	Hazlehead	Yorkshire	1
„ 30, 15·0 ...	Carmyle (No. 1 Pit) ..	Scotland, West ...	1
Aug. 1, 9·0 ...	Blackwell (A Pit) ...	Midland	3
„ 3, 6·0 ...	Hattonrigg (No. 3 Pit) ...	Scotland, West ...	1
„ 3, 10·30...	Holytown (No. 5 Pit) ...	Do.	1
„ 8, 8·30...	Ashington	Newcastle-upon-Tyne	1
„ 8, 15·0 ...	Auchenharvie (No. 5 Pit)	Scotland, West ...	1
„ 10, 7·0 ...	Gateside	Do.	2
„ 13, 7·0 ...	Auchenharvie (No. 1 Pit)	Do.	2
„ 13, 13·30...	Arniston	Scotland, East ...	1
„ 15, 5·20...	Greenhill	Do. ...	1

† No time given.

TABLE III.—*Continued*

1906.		Colliery.	
Aug.	16, 14·0 ..	Bonvilles Court	Sw
,,	20, 7·0 ..	Woodhall	Sc
,,	27, 15·0 ..	Mynydd Newydd	Sw
,,	31, 7·0 ..	Granville (No. 2 Pit) ...	Mi
Sept.	5, 21·0 ...	Throckley (Blucher Pit) ...	Ne
,,	7, 22·0 ...	Portland (No. 2 Pit) ...	Mi
,,	11, 8·0 ...	Oullwyn	Sw
,,	11, 11·30...	Gilmilnscroft	Sc
,,	15, 1·0 ...	Broughton Moor	Ne
,,	17, 6·0 ...	Craiglon	Sw
,,	21, 7·30...	Calderbank	Sc
,,	29, 2·50...	St. Helens	Du
Oct.	2, 13·30...	Auchincruive (No. 1 Pit)...	Sc
,,	3, 14·0 ...	International	Sw
,,	3, 20·0 ...	Brook Drift	
,,	5, 19·0 ...	Lanemark (Rigfoot) ...	Sc
,,	11, 5·15...	North Motherwell	Sc
,,	16, 7·45...	Teversall	Mi
,,	16, 14·0 ...	Cawdor	Sw
,,	17, 17·30...	North Motherwell	Sc
,,	26, 7·30...	Common (No. 11 Pit) ...	Sc
,,	28, 10·0 ...	Goatfoot	
Nov.	2, 7·30...	Mynydd Newydd	Sw
,,	3, 18·0 ...	South Moor (William Pit)	Du
,,	5, 8·30...	Broomrigg (No. 3 Pit) ...	Sc
,,	8, 6·30...	Prestongrange	Sc
,,	15, 6·15...	Devon	
,,	19, 21·0 ...	Springside (No. 11 Pit) ...	Sc
,,	24, 16·0 ...	Foxley (No. 4 Pit) ...	
,,	28, 7·30...	Gateside	
,,	29, 11·0 ...	Dunnikier	Sc
,,	29, 19·30...	Lower Varteg	So
Dec.	1, 3·0 ..	Backworth	Ne
,,	3, 4·30...	Darran	Sw
,,	5, 5·30...	Binchester	Du
,,	5, 8·15...	Sandwell Park	St
,,	5, 14·30...	Auchenharvie (No. 5 Pit)	Sc
,,	11, 13·0 ...	Aitkenhead	
,,	13, 9·20...	Saline	Sc
,,	16, 11·30...	Maesymarchog	Sw
,,	17, 3·0 ...	Morlais	
,,	17, 18·0 ...	Polmaise (No. 1 Pit) ...	Sc
,,	22, 12·30...	Kenmuirhill (No. 2 Pit) ...	
,,	24, 6·30...	Carriden	Sc
,,	24, 15·0 ...	Govan (No. 6 Pit) ...	Sc

TABLE IV.—BAROMETER, THERMOMETER, ETC., READINGS, 1906.

JANUARY, 1906.

KEW.								GLASGOW.							
	BAROMETER.				TEMPERATURE.				BAROMETER.				TEMPERATURE.		
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.	Direction of wind at noon.	Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.	Direction of wind at noon.
1	29·953	29·896	29·842	29·827	38·5	29·5	E	1	29·866	29·860	29·762	29·705	36·9	30·4	NE
2	29·796	29·774	29·606	29·589	44·4	38·7	SE	2	29·586	29·506	29·514	29·461	44·4	35·8	SE
3	29·495	29·497	29·552	29·615	50·1	38·7	SE	3	29·391	29·382	29·364	29·427	43·0	39·8	ENE
4	29·620	29·625	29·667	29·572	51·5	46·6	S	4	29·427	29·475	29·470	29·474	46·8	39·9	SE
5	29·693	29·765	29·869	29·853	51·5	46·9	W	5	29·510	29·604	29·644	29·578	44·9	40·3	W
6	29·422	29·268	29·373	29·593	52·1	43·4	WSW	6	29·338	29·266	29·341	29·487	43·8	38·2	NW
7	29·699	29·687	29·490	29·160	46·0	37·9	WSW	7	29·491	29·444	29·275	29·163	42·7	37·4	SW
8	29·155	29·248	29·438	29·627	47·3	38·6	WNW	8	29·129	29·211	29·298	29·382	40·1	36·5	E
9	29·656	29·464	29·338	29·423	51·2	36·7	SSW	9	29·263	28·954	28·804	28·848	45·2	37·8	SSW
10	29·455	29·553	29·685	29·911	45·2	35·9	W	10	29·022	29·212	29·460	29·673	42·9	37·7	W
11	30·078	30·176	30·115	29·946	46·0	32·0	WSW	11	29·768	29·753	29·486	29·306	45·0	36·6	SW
12	29·802	29·906	29·892	29·711	50·7	45·2	SW	12	29·406	29·473	29·466	29·405	42·3	38·2	SW
13	29·585	29·646	29·778	29·825	52·0	39·0	W	13	29·322	29·337	29·367	29·449	40·7	36·0	SW
14	29·990	30·130	30·125	30·079	48·7	36·0	SW	14	29·571	29·631	29·516	29·377	48·1	36·8	SW
15	30·005	29·920	29·742	29·700	47·0	42·0	S	15	29·256	29·314	29·300	29·312	48·2	38·2	S
16	29·807	29·909	29·791	29·664	48·6	37·9	SW	16	29·364	29·349	29·247	29·239	40·2	34·8	SW
17	29·735	29·948	30·039	30·035	46·8	40·4	W	17	29·328	29·481	29·609	29·629	42·6	34·3	W
18	29·885	29·530	29·354	29·623	49·4	39·7	SW	18	29·513	29·389	29·456	29·615	39·9	36·3	NNW
19	29·826	30·070	30·224	30·414	43·3	35·9	N	19	29·868	30·265	30·334	30·414	40·7	34·2	NW
20	30·520	30·567	30·481	30·265	40·3	30·3	W	20	30·365	30·249	29·986	29·960	47·0	34·0	SW
21	30·048	30·053	30·114	30·288	45·3	40·1	N	21	30·022	30·255	30·379	30·479	46·2	37·8	NE
22	30·410	30·487	30·503	30·570	40·3	33·3	N	22	30·498	30·518	30·501	30·509	39·1	31·1	NNE
23	30·604	30·663	30·633	30·621	35·1	27·0	SE	23	30·474	30·437	30·361	30·305	42·1	37·6	SW
24	30·574	30·517	30·361	30·199	39·8	30·1	S	24	30·208	30·039	29·688	29·516	47·0	40·8	SW
25	29·969	29·763	29·763	29·832	49·2	39·8	W	25	29·516	29·535	29·566	29·542	45·7	38·5	W
26	29·846	29·945	29·907	30·046	52·7	40·0	WSW	26	29·590	29·722	29·703	29·683	50·2	45·1	WSW
27	30·059	30·155	30·171	30·183	51·4	44·8	WSW	27	29·655	29·752	29·770	29·718	50·4	45·6	W
28	30·152	30·146	30·149	30·159	50·1	46·6	WSW	28	29·648	29·720	29·774	29·772	48·8	43·4	WSW
29	30·102	30·100	30·099	30·220	51·9	40·4	SW	29	29·720	29·882	29·949	30·024	44·1	38·8	W
30	30·298	30·373	30·335	30·341	48·1	34·8	W	30	30·064	30·094	30·153	30·234	46·0	39·0	W
31	30·352	30·413	30·392	30·349	46·3	34·3	W	31	30·223	30·179	30·034	30·039	48·1	40·1	SW

FEBRUARY, 1906.

1	30·279	30·239	30·217	30·242	47·1	40·4	WSW	1	30·038	29·997	29·926	29·856	45·9	41·	W
2	30·155	30·090	29·971	29·944	48·0	39·8	W	2	29·769	29·685	29·721	29·757	43·7	35·5	W
3	29·824	29·679	29·707	29·814	42·4	37·1	NW	3	29·639	29·733	29·894	30·026	40·4	33·8	NW
4	29·902	29·977	30·020	30·116	39·7	34·6	N	4	30·070	30·186	30·240	30·274	37·4	30·9	N
5	30·166	30·228	30·222	30·264	40·6	33·0	N	5	30·263	30·231	30·171	30·134	37·4	26·5	NW
6	30·264	30·287	30·229	30·213	37·2	32·1	NE	6	30·046	30·013	30·066	30·153	45·4	35·5	W
7	30·218	30·318	30·313	30·315	44·1	33·2	NNE	7	30·151	30·166	30·116	29·905	44·8	36·4	W
8	30·156	29·913	29·668	29·686	45·5	33·1	SW	8	29·562	29·398	29·419	29·460	45·1	30·4	NW
9	29·664	29·775	29·840	29·838	37·3	31·8	NW	9	29·561	29·681	29·674	29·466	35·0	26·6	NW
10	29·557	29·211	28·916	29·858	48·7	32·3	SW	10	28·846	28·648	28·452	28·420	43·2	30·5	SW
11	28·856	28·917	29·097	29·281	43·3	34·6	W	11	28·606	28·920	29·085	29·190	37·9	33·6	WNW
12	29·384	29·478	29·534	29·565	40·9	30·6	W	12	29·262	29·346	29·386	29·343	41·1	33·2	W
13	29·518	29·468	29·434	29·465	39·9	27·9	S	13	29·266	29·226	29·196	29·236	36·9	29·7	SE
14	29·551	29·633	29·636	29·641	43·6	30·3	SW	14	29·315	29·382	29·410	29·418	38·1	33·4	S
15	29·563	29·604	29·693	29·696	43·4	35·6	W	15	29·387	29·416	29·375	29·138	41·2	33·5	SW
16	29·567	29·568	29·582	29·525	49·7	40·0	SW	16	29·048	29·231	29·275	29·365	42·5	34·6	W
17	29·502	29·603	29·672	29·784	48·2	39·9	NNE	17	29·444	29·568	29·673	29·792	44·2	34·8	W
18	29·832	29·869	29·799	29·741	44·1	39·5	NE	18	29·823	29·837	29·681	29·715	42·3	33·8	SE
19	29·751	29·734	29·652	29·762	46·0	38·8	S	19	29·627	29·610	29·608	29·738	39·3	33·9	E
20	29·899	30·041	30·084	30·175	45·4	34·7	WNW	20	29·842	29·936	30·018	30·098	43·2	32·6	WNW
21	30·183	30·222	30·177	30·189	44·3	29·4	NW	21	30·119	30·153	30·126	30·126	42·1	31·5	W
22	30·153	30·101	29·955	29·790	44·1	25·6	SSE	22	30·066	30·013	29·883	29·823	41·0	29·8	NE
23	29·607	29·555	29·567	29·656	38·7	31·4	ENE	23	29·751	29·739	29·668	29·610	39·2	30·9	ENE
24	29·692	29·728	29·728	29·710	41·5	29·9	W	24	29·555	29·529	29·445	29·274	37·1	27·0	NW
25	29·454	29·414	29·482	29·555	48·3	37·3	W	25	28·961	28·943	29·012	29·093	42·5	34·5	W
26	29·526	29·464	29·350	29·313	48·5	37·1	SW	26	29·108	29·121	29·107	29·118	41·1	33·8	SSW
27	29·227	29·196	29·251	29·405	45·7	36·0	W	27	29·107	29·231	29·419	29·631	39·5	33·7	N
28	29·627	29·847	29·824	29·743	45·0	34·2	NW	28	29·662	29·476	29·370	29·504	46·1	29·9	WSW

MARCH, 1906.

KEW.											
	Barometer.				Temperature.				Barom		
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M	Max	Min.	Direction of wind at noon.	Date.	4 A.M.	10 A.M.	
1	29·753	29·773	29·627	29·657	49·4	44·3	WSW	1	29·519	29·48	
2	29·667	29·732	29·966	30·209	50·0	34·4	N	2	29·719	29·87	
3	30·336	30·444	30·399	30·422	47·6	30·0	WSW	3	30·159	30·16	
4	30·376	30·372	30·282	30·252	54·4	35·6	SW	4	30·146	30·19	
5	30·124	30·107	30·105	30·188	51·5	33·9	SW	5	29·858	29·79	
6	30·219	30·316	30·238	30·287	60·6	47·3	SSW	6	29·818	29·84	
7	30·275	30·270	30·150	30·136	61·0	39·6	SSW	7	29·914	29·84	
8	30·028	29·906	29·788	29·790	51·2	45·3	SW	8	29·573	29·44	
9	29·794	29·854	29·860	29·955	48·4	40·0	WNW	9	29·369	29·50	
10	30·000	30·029	29·921	29·758	48·3	36·4	SW	10	29·863	29·84	
11	29·599	29·439	29·138	29·170	52·9	40·8	SW	11	29·348	28·98	
12	29·248	29·375	29·702	29·920	40·7	32·1	NNW	12	29·178	29·53	
13	29·858	29·885	29·866	29·824	39·1	29·6	WSW	13	29·742	29·75	
14	29·757	29·915	30·064	30·075	43·8	33·0	NE	14	29·838	29·90	
15	29·941	29·918	29·857	29·891	54·0	40·5	WSW	15	29·542	29·32	
16	29·965	29·966	30·011	30·059	55·7	48·9	WSW	16	29·552	29·53	
17	30·071	30·077	29·994	29·973	61·2	45·8	sW	17	29·520	29·53	
18	29·928	29·917	29·875	29·893	49·4	38·2	W	18	29·784	29·85	
19	29·858	30·074	30·161	30·265	43·8	37·1	N	19	30·163	30·27	
20	30·265	30·228	30·086	30·026	44·9	36·3	NW	20	30·370	30·29	
21	30·007	30·052	30·084	30·161	42·2	32·7	NE	21	30·263	30·30	
22	30·168	30·176	30·096	30·032	40·3	30·7	NE	22	30·304	30·26	
23	29·919	29·924	29·892	29·865	40·0	28·0	NE	23	29·969	30·10	
24	29·787	29·718	29·637	29·640	40·7	32·0	NNE	24	30·034	29·96	
25	29·588	29·617	29·595	29·674	41·1	31·6	N	25	29·907	29·92	
26	29·693	29·744	29·757	29·834	41·5	30·4	NNE	26	29·936	29·99	
27	29·859	29·936	29·917	30·018	43·5	33·9	NE	27	30·100	30·11	
28	30·042	30·089	30·044	30·028	44·0	32·6	E	28	30·172	30·13	
29	30·010	30·100	30·130	30·206	45·1	32·2	N	29	30·094	30·14	
30	30·228	30·260	30·213	30·243	47·6	29·3	W	30	30·151	30·16	
31	30·242	30·288	30·277	30·337	51·7	39·7	NW	31	30·203	30·23	

APRIL, 1906.

1	30·369	30·429	30·427	30·479	50·2	40·9	NNE	1	30·346	30·3
2	30·488	30·519	30·451	30·447	45·6	35·3	NE	2	30·460	30·4
3	30·396	30·400	30·324	30·316	59·6	36·6	ESE	3	30·427	30·3
4	30·255	30·190	30·026	29·963	55·5	36·3	SE	4	30·073	29·9
5	29·876	29·832	29·828	29·948	61·3	38·9	SE	5	29·714	29·7
6	30·091	30·276	30·334	30·462	58·3	38·3	NE	6	30·235	30·3
7	30·445	30·451	30·368	30·411	60·1	32·0	E	7	30·341	30·3
8	30·397	30·478	30·483	30·573	58·3	40·4	N	8	30·416	30·5
9	30·577	30·573	30·470	30·493	58·1	40·0	NE	9	30·669	30·6
10	30·427	30·392	30·273	30·271	62·2	36·2	NE	10	30·489	30·4
11	30·231	30·233	30·139	30·158	66·3	40·1	NE	11	30·301	30·2
12	30·126	30·104	30·031	30·053	71·1	40·3	S	12	30·091	30·0
13	30·015	30·048	30·027	30·139	67·9	49·1	SW	13	29·875	29·9
14	30·296	30·434	30·472	30·558	52·4	38·9	NNE	14	30·313	30·3
15	30·558	30·572	30·478	30·469	57·2	32·0	NE	15	30·364	30·3
16	30·394	30·318	30·148	30·068	63·4	32·4	W	16	30·157	30·0
17	29·964	29·874	29·769	29·784	59·3	38·0	NW	17	29·938	29·9
18	29·727	29·701	29·656	29·687	46·2	39·6	NNE	18	29·911	29·9
19	29·640	29·688	29·745	29·876	49·0	34·7	NNE	19	29·915	29·8
20	29·920	29·969	29·969	30·021	54·9	30·6	SW	20	29·623	29·6
21	30·023	30·015	29·915	29·866	58·6	42·0	W	21	29·546	29·5
22	29·839	29·900	29·872	29·967	55·0	40·7	W	22	29·492	29·6
23	30·015	30·093	30·067	30·089	49·5	35·5	NNW	23	30·040	30·0
24	30·035	29·972	29·898	29·843	48·0	32·4	NW	24	29·969	29·9
25	29·783	29·850	29·858	29·860	47·3	35·4	E	25	29·960	30·0
26	29·723	29·618	29·587	29·729	51·0	31·5	S	26	29·501	29·7
27	29·803	29·811	29·700	29·590	54·9	32·4	NW	27	29·718	29·6
28	29·362	29·366	29·342	29·348	50·1	35·4	WNW	28	29·213	29·1
29	29·331	29·343	29·327	29·356	49·7	32·3	SSW	29	29·054	29·1
30	29·366	29·446	29·465	29·543	49·0	35·4	NNE	30	29·449	29·5

MAY, 1906.

KEW.								GLASGOW.							
	BAROMETER.				TEMPERATURE.				BAROMETER.				TEMPERATURE.		
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.	Direction of wind at noon.	Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.	Direction of wind at noon.
1	29·569	29·636	29·646	29·703	54·4	34·1	NW	1	29·592	29·579	29·549	29·554	49·0	33·3	NW
2	29·714	29·746	29·707	29·685	50·6	36·9	S	2	29·544	29·509	29·404	29·332	46·4	33·5	S
3	29·707	29·765	29·746	29·773	59·3	47·5	SSW	3	29·394	29·446	29·447	29·490	52·5	43·2	S
4	29·798	29·895	29·978	30·107	60·0	48·6	SW	4	29·516	29·611	29·789	29·933	51·1	42·5	W
5	30·171	30·196	30·169	30·146	58·7	41·1	SW	5	29·962	29·912	29·794	29·727	49·4	36·5	SSE
6	30·083	30·104	30·102	30·131	56·0	50·0	SW	6	29·656	29·706	29·737	29·793	57·5	48·9	SSW
7	30·123	30·158	30·102	30·094	64·7	50·7	SSW	7	29·854	29·921	29·947	30·021	62·8	48·9	SSW
8	30·043	29·979	29·851	29·854	73·3	43·9	NNE	8	30·026	30·018	29·934	29·900	58·4	49·1	NW
9	29·783	29·779	29·742	29·777	59·8	48·4	NW	9	29·828	29·824	29·812	29·828	51·0	43·4	NE
10	29·741	29·761	29·724	29·737	49·6	45·0	NE	10	29·789	29·732	29·633	29·594	51·4	40·8	W
11	29·715	29·718	29·680	29·719	58·1	45·0	S	11	29·540	29·534	29·559	29·642	47·9	39·6	SE
12	29·730	29·804	29·841	29·938	70·0	49·4	SSE	12	29·707	29·807	29·903	30·001	58·4	45·2	N
13	29·958	29·996	29·931	29·971	71·3	50·8	NE	13	30·045	30·075	30·035	30·035	61·0	50·3	NE
14	29·906	29·887	29·865	29·896	63·2	47·0	NNE	14	30·050	30·065	30·028	30·017	56·3	46·2	NE
15	29·815	29·793	29·637	29·602	59·2	43·3	N	15	29·869	29·705	29·578	29·499	51·3	41·0	WNW
16	29·537	29·479	29·416	29·471	54·7	44·0	WNW	16	29·501	29·546	29·553	29·580	49·3	41·5	N
17	29·466	29·495	29·481	29·504	51·0	40·0	NNW	17	29·511	29·440	29·432	29·480	48·7	40·3	N
18	29·512	29·554	29·562	29·620	55·0	33·1	ENE	18	29·487	29·640	29·701	29·740	51·3	40·6	ENE
19	29·649	29·659	29·626	29·683	62·0	40·4	N	19	29·728	29·726	29·729	29·770	48·6	43·1	NE
20	29·695	29·716	29·735	29·778	49·8	41·9	NW	20	29·818	29·876	29·910	29·982	54·8	39·1	ENE
21	29·759	29·819	29·868	29·907	52·6	43·9	N	21	29·952	29·952	29·903	29·888	46·4	35·1	W
22	29·897	29·912	29·884	29·861	56·1	44·0	E	22	29·881	29·884	29·884	29·888	47·5	39·3	E
23	29·801	29·770	29·696	29·671	69·0	48·2	S	23	29·866	29·834	29·792	29·755	49·5	39·5	E
24	29·649	29·713	29·784	29·916	64·7	49·2	SW	24	29·704	29·710	29·668	29·652	48·5	44·0	ENE
25	29·980	30·026	30·030	30·077	62·5	45·7	SW	25	29·688	29·744	29·728	29·738	54·6	45·8	S
26	30·056	29·991	29·915	29·928	60·6	47·8	S	26	29·754	29·766	29·752	29·741	58·1	42·8	WSW
27	29·894	29·904	29·930	29·999	65·1	53·6	SW	27	29·710	29·708	29·708	29·708	64·7	48·1	SSW
28	29·954	30·036	30·047	30·061	71·8	56·3	SW	28	29·694	29·796	29·824	29·806	60·4	47·2	NE
29	30·058	30·057	30·041	30·074	69·5	53·8	W	29	29·769	29·810	29·798	29·776	55·7	51·0	SW
30	30·050	30·028	29·927	29·887	67·3	50·0	W	30	29·751	29·798	29·752	29·647	57·3	48·9	W
31	29·753	29·677	29·645	29·679	62·6	48·7	W	31	29·551	29·515	29·480	29·411	54·2	7·2	W

JUNE, 1906.

1	29·605	29·525	29·515	29·665	58·9	46·7	WSW	1	29·325	29·415	29·563	29·714	57·1	44·3	E
2	29·797	29·910	29·950	30·033	62·3	45·3	NW	2	29·817	29·895	29·949	30·031	68·1	48·4	W
3	30·068	30·157	30·181	30·216	68·3	48·3	NNW	3	30·082	30·131	30·181	30·216	63·1	46·9	W
4	30·251	30·321	30·338	30·378	60·6	46·9	NE	4	30·262	30·309	30·291	30·328	61·5	43·8	NE
5	30·372	30·377	30·311	30·351	64·3	41·2	NE	5	30·327	30·314	30·252	30·252	63·6	45·1	ENE
6	30·330	30·330	30·267	30·273	68·0	44·5	E	6	30·233	30·231	30·199	30·191	66·6	47·3	SW
7	30·257	30·230	30·182	30·193	71·2	42·5	NE	7	30·176	30·196	30·174	30·189	66·8	52·6	W
8	30·188	30·177	30·135	30·182	72·7	47·0	NE	8	30·193	30·219	30·186	30·182	69·4	50·6	NE
9	30·187	30·211	30·184	30·239	69·9	50·4	NE	9	30·194	30·215	30·199	30·217	69·5	49·4	W
10	30·249	30·253	30·196	30·236	68·6	47·3	NE	10	30·230	30·251	30·227	30·255	76·6	51·3	E
11	30·235	30·258	30·183	30·195	69·0	47·8	NE	11	30·261	30·253	30·182	30·183	78·0	54·3	NE
12	30·179	30·158	30·074	30·048	72·0	47·1	NE	12	30·164	30·138	30·101	30·146	73·2	52·2	W
13	30·047	30·092	30·084	30·121	61·5	48·6	NNE	13	30·136	30·159	30·130	30·144	67·0	51·8	E
14	30·107	30·113	30·079	30·062	56·0	48·5	N	14	30·124	30·121	30·050	30·062	66·1	50·6	WSW
15	30·023	29·974	29·916	29·930	57·8	47·5	N	15	30·061	30·072	30·094	30·154	59·2	50·1	E
16	29·935	29·950	29·917	29·970	63·1	47·1	NE	16	30·176	30·136	30·080	30·084	65·3	47·4	NE
17	29·953	29·984	29·989	30·060	68·4	49·2	S	17	30·081	30·071	30·041	30·043	58·9	51·6	E
18	30·095	30·129	30·110	30·176	72·1	45·2	S	18	30·084	30·079	30·059	30·125	66·0	51·2	ENE
19	30·213	30·248	30·231	30·300	75·8	51·0	W	19	30·145	30·164	30·163	30·189	68·6	48·5	SW
20	30·329	30·352	30·317	30·329	77·5	53·0	SSW	20	30·180	30·170	30·120	30·134	65·6	54·6	SW
21	30·320	30·315	30·255	30·229	76·5	58·6	W	21	30·150	30·180	30·134	30·094	65·5	57·3	W
22	30·177	30·150	30·092	30·093	75·7	61·1	NW	22	30·051	30·059	30·040	30·044	67·2	57·1	WSW
23	30·046	29·980	29·879	29·839	81·6	57·4	S	23	29·999	29·935	29·844	29·764	66·3	54·7	NNW
24	29·762	29·846	29·921	30·031	71·1	58·7	WNW	24	29·711	29·730	29·734	29·813	66·8	52·7	SW
25	30·086	30·110	30·064	30·076	70·1	55·6	SW	25	29·823	29·782	29·679	29·712	59·0	48·3	S
26	30·067	30·043	29·989	29·971	72·0	57·4	SW	26	29·724	29·698	29·643	29·629	62·4	51·8	SW
27	29·924	29·907	29·893	29·904	74·0	54·0	SW	27	29·609	29·647	29·700	29·744	59·9	51·0	WSW
28	29·873	29·839	29·775	29·720	74·3	56·9	SW	28	29·759	29·787	29·802	29·915	61·5	50·2	W
29	29·672	29·876	30·074	30·181	59·2	47·0	N	29	29·995	30·051	30·049	30·087	57·8	44·7	W
30	30·197	30·176	30·105	30·081	65·0	44·3	W	30	30·047	30·034	29·978	29·970	57·1	46·2	W

JULY, 1906.

KEW.								GLASGOW.							
	BAROMETER.				TEMPERATURE.				BAROMETER.				TEMPERATURE.		
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min	Direction of wind at noon.	Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min	Direction of wind at noon.
1	30·062	30·068	30·043	30·062	67·2	47·0	NNW	1	29·970	29·996	29·992	30·019	59·5	44·1	SE
2	30·062	30·081	30·047	30·089	70·3	49·7	E	2	30·014	30·022	29·999	30·031	62·9	48·8	SW
3	30·088	30·090	30·070	30·127	69·8	51·2	ENE	3	30·052	30·074	30·074	30·123	66·4	50·1	WNW
4	30·116	30·092	30·017	30·029	74·0	51·0	N	4	30·112	30·092	30·030	30·022	65·9	47·2	ENE
5	29·993	29·966	29·914	29·932	76·5	52·0	NE	5	29·978	29·938	29·843	29·843	72·7	50·3	NE
6	29·912	29·914	29·897	29·932	72·4	54·6	WSW	6	29·828	29·817	29·839	29·870	61·3	54·1	W
7	29·959	30·020	30·021	30·092	75·0	55·8	W	7	29·874	29·862	29·865	29·892	64·8	48·1	SW
8	30·105	30·142	30·154	30·188	76·0	56·7	WSW	8	29·925	30·034	30·100	30·160	63·7	52·5	W
9	30·216	30·240	30·212	30·204	72·1	55·2	N	9	30·165	30·177	30·173	30·136	62·9	49·7	WSW
10	—	30·150	30·116	30·164	69·6	53·0	E	10	30·116	30·121	30·112	30·160	61·9	51·5	W
11	30·153	30·160	30·135	30·173	65·9	51·6	N	11	30·163	30·176	30·156	30·178	61·8	45·1	WNW
12	30·172	30·180	30·139	30·154	65·0	51·7	N	12	30·182	30·166	30·093	30·062	65·9	45·1	W
13	30·105	30·078	30·040	30·017	66·5	47·0	W	13	29·956	29·896	29·858	29·882	62·4	52·8	SW
14	29·970	30·015	30·009	30·044	74·9	57·7	W	14	29·875	29·851	29·833	29·716	57·2	48·8	SW
15	29·987	29·950	29·910	30·017	70·7	55·8	WSW	15	29·564	29·712	29·750	29·812	59·1	51·6	W
16	30·033	30·008	29·970	30·005	73·1	51·3	W	16	29·750	29·624	29·620	29·710	59·5	49·2	W
17	30·029	30·068	30·049	30·011	78·4	59·7	W	17	29·790	29·774	29·749	29·700	61·6	51·0	SW
18	29·988	29·946	29·825	29·798	80·8	58·3	SW	18	29·659	29·601	29·489	29·399	65·1	54·3	SW
19	29·776	29·835	29·877	29·927	66·1	54·4	W	19	29·434	29·516	29·624	29·658	56·2	47·5	W
20	29·887	29·885	29·843	29·924	68·6	52·4	W	20	29·610	29·628	29·688	29·748	57·7	45·1	W
21	29·975	29·977	29·951	29·957	68·1	48·9	SW	21	29·768	29·823	29·708	29·798	67·0	46·2	WSW
22	29·951	29·971	29·954	30·008	78·0	63·8	WNW	22	29·757	29·763	29·708	29·873	67·5	57·0	SW
23	29·994	29·975	29·903	29·900	80·2	61·6	S	23	29·849	29·791	29·755	29·801	60·0	50·4	N
24	29·916	29·979	29·997	30·057	70·9	57·2	NW	24	29·827	29·867	29·887	29·949	59·2	49·8	SW
25	30·113	30·144	30·097	30·085	75·7	49·9	E	25	29·992	30·039	30·020	29·995	66·1	50·2	SW
26	30·014	29·939	29·840	29·830	75·1	55·8	E	26	29·932	29·884	29·793	29·766	73·0	54·8	ESE
27	29·802	29·817	29·840	29·917	76·1	59·1	NE	27	29·786	29·815	29·843	29·837	62·2	53·5	NE
28	29·913	29·925	29·895	29·913	74·5	56·1	SW	28	29·785	29·722	29·696	29·759	65·8	51·9	SE
29	29·910	29·928	29·932	29·947	73·0	59·2	NNW	29	29·794	29·851	29·861	29·903	70·1	53·4	WSW
30	29·922	29·907	29·861	29·862	80·1	59·2	E	30	29·902	29·892	29·832	29·812	63·4	51·9	ENE
31	29·811	29·880	29·900	30·007	77·7	59·9	W	31	29·783	29·766	29·754	29·827	64·0	56·7	E

AUGUST, 1906.

1	30·032	30·078	30·036	30·037	76·6	54·1	SW	1	29·871	29·895	29·855	29·820	65·1	52·8	SE
2	29·977	29·912	29·761	29·636	83·1	58·4	S	2	29·725	29·669	29·572	29·473	66·1	60·5	SSE
3	29·699	29·760	29·787	29·851	73·1	59·0	SW	3	29·425	29·460	29·460	29·510	63·0	56·4	SW
4	29·911	29·995	30·044	30·164	72·5	57·3	WSW	4	29·592	29·509	29·818	29·914	61·5	54·4	SW
5	30·188	30·231	30·196	30·206	75·0	54·9	SW	5	29·954	30·028	30·088	30·114	60·9	53·1	WSW
6	30·197	30·200	30·143	30·129	77·7	58·0	WSW	6	30·128	30·144	30·115	30·098	71·3	47·7	SW
7	30·101	30·079	30·021	30·034	80·8	57·7	SW	7	30·060	30·018	29·964	29·977	65·0	54·5	NE
8	30·006	29·963	29·845	29·816	82·0	58·8	S	8	29·955	29·927	29·836	29·824	69·4	56·4	SW
9	29·827	29·859	29·840	29·843	74·3	57·2	W	9	29·777	29·777	29·751	29·751	63·9	54·5	W
10	29·808	29·790	29·714	29·719	70·9	58·9	SW	10	29·692	29·644	29·583	29·606	58·6	52·1	SE
11	29·707	29·754	29·795	29·829	68·3	55·3	NW	11	29·655	29·713	29·707	29·711	60·8	51·7	ENE
12	29·817	29·832	29·816	29·799	69·9	56·0	SSW	12	29·658	29·607	29·566	29·538	60·1	53·2	E
13	29·705	29·626	29·581	29·626	77·9	60·8	S	13	29·415	29·402	29·353	29·404	63·4	57·4	SE
14	29·651	29·657	29·619	29·676	71·7	57·6	S	14	29·435	29·430	29·383	29·414	66·2	53·2	SSE
15	29·714	29·750	29·730	29·790	69·7	55·9	SW	15	29·413	29·452	29·466	29·488	63·4	54·2	SW
16	29·810	29·837	29·817	29·844	67·6	52·9	WSW	16	29·499	29·537	29·574	29·625	59·8	52·1	W
17	29·804	29·812	29·804	29·851	65·0	53·3	W	17	29·624	29·638	29·687	29·797	58·0	51·5	WNW
18	29·847	29·946	30·001	30·091	64·6	50·9	NNW	18	29·851	29·932	29·977	30·040	63·8	49·3	WNW
19	30·110	30·174	30·153	30·178	66·7	52·0	NW	19	30·037	30·051	30·015	29·953	60·1	46·2	W
20	30·142	30·118	30·072	30·090	71·6	50·6	SW	20	30·082	29·704	29·744	29·873	64·1	54·4	WSW
21	30·092	30·111	30·106	30 094	76·6	61·6	W	21	29·902	29·953	29·951	29·904	62·4	53·1	SW
22	30·044	29·995	29·896	29·897	86·0	56·4	S	22	29·788	29·804	29·827	29·862	62·2	53·1	SW
23	29·855	29·916	29·928	29·988	81·1	56·9	SW	23	29·908	29·975	29·946	29·908	59·7	50·2	ENE
24	29·955	29·940	29·913	29·913	75·1	62·4	SW	24	29·840	29·826	29·753	29·663	65·3	50·5	N
25	29·723	29·705	29·888	30·043	68·7	56·3	W	25	29·465	29·557	29·735	29·875	60·8	52·8	W
26	30·096	30·130	30·100	30·128	72·4	54·7	SW	26	29·908	29·896	29·904	29·997	62·5	50·1	SE
27	30·140	30·188	30·220	30·345	75·5	59·0	N	27	30·079	30·195	30·241	30·296	61·2	52·1	SE
28	30·382	30·411	30·334	30·345	70·3	52·3	E	28	30·296	30·309	30·250	30·220	69·7	55·7	WSW
29	30·302	30·280	30·178	30·172	74·6	46·0	ESE	29	30·157	30·140	30·099	30·065	70·0	57·9	SW
30	30·124	30·122	30·047	30·065	83·4	48·6	E	30	30·025	30·036	29·974	29·979	70·7	51·3	SW
31	30·059	30·069	30·041	30·079	90·9	55·9	S	31	29·969	29·981	29·945	29·965	76·2	49·2	SW

SEPTEMBER, 1906.

KEW.

Date.	Barometer. 4 A.M.	10 A.M.	4 P.M.	10 P.M.	Temperature. Max	Min.	Direction of wind at noon.
1	30·041	30·043	29·972	29·987	91·7	60·4	SE
2	29·960	29·958	29·904	29·940	91·7	59·6	SSE
3	29·928	29·932	29·937	30·041	84·9	57·0	SW
4	30·076	30·101	30·080	30·092	75·3	59·7	N
5	30·078	30·117	30·024	30·013	70·9	53·8	N
6	29·914	29·938	29·952	30·032	72·9	59·5	W
7	30·056	30·118	30·068	30·071	73·5	59·7	SW
8	30·054	30·085	30·058	30·116	77·1	55·4	W
9	30·156	30·219	30·199	30·255	67·5	53·3	N
10	30·258	30·279	30·250	30·321	64·0	47·8	N
11	30·318	30·342	30·262	30·267	68·6	42·3	SW
12	30·224	30·206	30·157	30·134	69·0	44·2	S
13	30·050	29·997	29·874	29·791	69·3	54·9	S
14	29·815	29·814	29·745	29·721	67·0	52·0	SW
15	29·538	29·597	29·571	29·610	63·0	50·0	W
16	29·702	29·826	29·908	30·000	58·2	48·6	NW
17	29·983	30·066	30·157	30·182	64·4	51·4	N
18	30·045	30·160	30·155	30·141	64·0	55·0	ENE
19	30·111	30·122	30·115	30·167	60·6	55·4	N
20	30·165	30·195	30·207	30·264	63·3	51·4	N
21	30·274	30·320	30·288	30·329	63·9	50·7	?
22	30·327	30·365	30·326	30·373	62·7	49·8	N
23	30·384	30·420	30·392	30·442	59·5	49·6	NNE
24	30·420	30·435	30·417	30·434	61·6	49·0	E
25	30·446	30·483	30·474	30·527	59·7	44·7	E
26	30·539	30·583	30·548	30·580	61·1	40·8	NE
27	30·588	30·601	30·542	30·564	64·6	38·9	E
28	30·523	30·527	30·406	30·383	60·0	38·6	SE
29	30·342	30·326	30·241	30·249	60·6	37·4	ENE
30	30·225	30·220	30·124	30·130	66·3	41·2	E

GLASGOW.

Date.	Barometer. 4 A.M.	10 A.M.	4 P.M.	10 P.M.	Temperature. Max	Min.	Direction of wind at noon.
1	29·959	29·959	29·900	29·899	83·5	54·6	NW
2	29·851	29·848	29·808	29·876	81·7	59·5	NE
3	29·899	29·946	30·010	30·064	65·9	53·7	W
4	30·090	30·109	30·081	30·051	62·1	47·2	WSW
5	29·968	29·881	29·669	29·581	58·9	53·5	SW
6	29·653	29·767	29·789	29·819	61·0	53·0	W
7	29·803	29·859	29·889	29·844	62·0	55·2	SW
8	29·847	29·909	29·964	30·035	61·1	52·4	W
9	30·071	30·133	30·173	30·221	58·9	49·4	W
10	30·244	30·279	30·250	30·262	59·2	44·6	SW
11	30·221	30·168	30·087	30·047	63·5	42·4	S
12	29·984	30·037	30·020	29·915	62·2	51·0	W
13	29·776	29·714	29·658	29·638	59·6	50·6	S
14	29·507	29·473	29·494	29·375	57·5	48·0	W
15	29·273	29·295	29·347	29·479	56·2	47·5	SW
16	29·624	29·804	29·934	30·002	59·9	47·6	NNW
17	30·128	30·223	30·275	30·345	61·8	39·9	W
18	30·389	30·394	30·345	30·337	59·8	46·5	E
19	30·290	30·288	30·265	30·287	57·7	53·0	NE
20	30·286	30·305	30·301	30·339	59·8	50·3	NE
21	30·343	30·388	30·379	30·387	60·4	52·1	E
22	30·374	30·389	30·380	30·439	62·7	45·5	N
23	30·464	30·510	30·484	30·518	57·5	47·4	E
24	30·515	30·498	30·441	30·443	56·1	40·2	E
25	30·427	30·443	30·444	30·473	58·5	48·2	SSW
26	30·488	30·512	30·497	30·502	58·3	48·4	WSW
27	30·498	30·509	30·471	30·489	59·8	47·9	SW
28	30·457	30·457	30·377	30·385	59·9	40·5	W
29	30·317	30·315	30·225	30·216	62·3	37·6	WSW
30	30·180	30·156	30·049	30·040	60·5	36·9	NW

OCTOBER, 1906.

1	30·079	30·060	29·973	29·898	68·4	47·3	S	1	29·964	29·917	29·746	29·643	61·0	47·6	SE
2	29·750	29·711	29·439	29·164	62·6	58·4	SSW	2	29·566	29·538	29·483	29·568	58·7	41·2	WSW
3	29·529	29·787	29·884	29·944	62·1	56·0	NNW	3	29·640	29·771	29·812	29·869	57·1	48·9	W
4	29·950	29·934	29·856	29·797	61·9	51·6	S	4	29·838	29·822	29·708	29·556	57·1	49·0	E
5	29·725	29·745	29·755	29·853	65·2	57·4	SSW	5	29·484	29·510	29·549	29·676	58·8	52·1	SW
6	29·933	30·006	30·012	30·015	63·5	51·0	SW	6	29·728	29·768	29·730	29·700	58·9	46·4	SSW
7	29·976	29·963	29·903	29·854	65·2	55·6	S	7	29·636	29·630	29·598	29·630	63·1	52·3	SSW
8	29·799	29·814	29·756	29·766	63·5	54·0	S	8	29·561	29·508	29·516	29·585	58·1	51·7	SE
9	29·776	29·823	29·824	29·819	60·2	51·4	SE	9	29·628	29·742	29·788	29·852	59·4	51·0	E
10	29·795	29·819	29·780	29·759	67·2	56·0	ENE	10	29·816	29·784	29·771	29·778	60·5	53·0	NE
11	29·703	29·743	29·714	29·733	69·3	53·2	SSE	11	29·750	29·740	29·647	29·572	58·9	53·4	E
12	29·749	29·762	29·718	29·703	62·9	52·7	SW	12	29·500	29·540	29·531	29·542	55·6	46·0	W
13	29·595	29·573	29·549	29·641	54·4	42·2	NW	13	29·539	29·580	29·671	29·829	46·6	37·3	N
14	29·740	29·885	29·926	29·960	51·6	37·9	N	14	29·854	29·820	29·687	29·599	52·5	32·6	SSW
15	29·873	29·816	29·726	29·715	59·6	37·6	SW	15	29·465	29·439	29·409	29·396	53·1	45·2	SW
16	29·676	29·704	29·687	29·757	59·5	50·2	SW	16	29·370	29·350	29·359	29·380	51·9	42·4	SW
17	29·743	29·805	29·826	29·880	59·2	50·3	W	17	29·382	29·454	29·526	29·684	49·5	40·0	SW
18	29·831	29·769	29·713	29·643	61·4	53·2	S	18	29·742	29·804	29·828	29·840	47·3	39·4	NE
19	29·608	29·740	29·773	29·824	57·8	44·1	SW	19	29·743	29·671	29·518	29·468	42·2	37·9	NW
20	29·847	29·899	29·842	29·813	57·9	37·9	WSW	20	29·523	29·657	29·702	29·726	51·7	39·4	W
21	29·856	29·923	29·913	29·932	66·5	53·6	S	21	29·702	29·769	29·751	29·744	57·4	42·6	NE
22	29·893	29·873	29·871	29·930	65·8	54·9	SW	22	29·659	29·615	29·504	29·612	59·7	53·5	SSE
23	29·929	30·022	30·031	30·087	62·3	52·0	SW	23	29·653	29·698	29·724	29·775	58·2	50·1	S
24	30·088	30·124	30·136	30·245	62·8	44·6	SW	24	29·860	29·944	30·025	30·118	52·1	44·0	SW
25	30·304	30·372	30·384	30·405	54·8	38·3	N	25	30·189	30·269	30·247	30·157	51·1	39·1	SSW
26	30·311	30·231	30·080	30·018	56·0	35·0	N	26	29·987	29·809	29·669	29·766	53·2	46·5	S
27	29·949	30·041	30·053	30·054	52·0	39·4	NW	27	29·833	29·881	29·737	29·578	50·7	40·5	SW
28	29·926	29·768	29·525	29·507	54·5	39·3	SSW	28	29·388	29·226	29·190	29·200	51·5	37·7	WSW
29	29·539	29·610	29·522	29·453	51·5	40·9	SW	29	29·186	29·176	29·136	29·162	41·8	35·3	SW
30	29·270	29·181	29·187	29·236	49·3	43·6	S	30	29·216	29·329	29·332	29·351	43·1	33·1	NE
31	29·337	29·476	29·498	29·471	49·9	41·5	N	31	29·321	29·534	29·595	29·640	53·9	42·1	E

INDEX TO VOL. XXXIII.

EXPLANATIONS.

The — at the beginning of a line denotes the repetition of a word; and in the case of Names, it includes both the Christian Name and the Surname; or, in the case of the name of any Firm, Association or Institution, the full name of such Firm, etc.

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S. I.—The Mining Institute of Scotland.
S. S.—The South Staffordshire and Warwickshire Institute of Mining Engineers.

A.

Aasvogelrand, South Africa, quartzites, dip of, 548.
ABEL, SIR FREDERICK A., quoted, 308, 326.
ABELL, W. PRICE, *improvements required in inland navigation*, 364.
Abolesheff bay, eastern Siberia, pyrites lodes, 719.
Accidents, fatal, coal and gas outbursts, 313.
—, —, — output and, 332.
Accounts, S.I., 154.
Accumulators, Pollak, electric power-station, Grand Hornu, 653.
ACKROYD, ALFRED, election, M.G., 290.
Adalia, Asia Minor, chrome-iron-ore, 710.
Adana, Asia Minor, chrome-iron-ore, 710.
Address, presidential, 330.
Advance bore-holes, precaution against coal and gas outbursts, 317.
Aerolith, liquid air rescue-apparatus, 170.
AGNEW electric drill, Gay Coal and Coke Company, 564.
AHNERT, E., gold-bearing regions of Siberia, 714.
AHNERT, E., M. M. IVANOFF, A. KHLAPONIN, P. RIPPAS and P. YAVOROVSKY, gold-bearing regions of Siberia, 714.
Air, liquid, use in rescue-apparatus, 2, 170.
Air-compression, adiabatic, advantages, 445.
Air-compressors, air-lift pumps, 495.
— —, electrically-driven, 501.
— —, — —, economies effected by, 338.
— —, inbye, advantages, 445.
Air-currents, measuring velocities of, 58 *et seq.*
Air-lift pumps, 492.
— — —, efficiency, 498, 499.
— — —, limitations, 493.
— — —, water-supplies from bore-holes, 485.
Akmolinsk, Siberia, coal-fields, 526.
Alaska, coal-fields, Manchurian coal-fields and, 712.
Albion colliery explosion, cause, 185.
Aldan river, Siberia, gold-placers, 715.
ALDIS, W. STEADMAN, quoted, 568, 586, 625, 631.
Alexandretta, Asia Minor, chrome-iron-ore, 710.
Alghero, Sardinia, copper-ores, 685.
ALISON, M. S., quoted, 553.
ALLERTON, LORD, quoted, 29.
Almeria, Spain, ore-deposits, 699.
Alps, Piedmontese, graphite-deposits, 683.
—, South Africa and, structural geology compared, 552.
Altofts collieries, experimental gallery, 205.
— —, — —, pneumatogen trial at, 251.
— —, — —, report on rescue-work, 209.
— —, explosion, 279.

NOVEMBER, 1906.

KEW.								GLASGOW.							
	Barometer.				Tempera-ture.				Barometer.				Tempera-ture.		
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.	Direction of wind at noon.	Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max	Min.	Direction of wind at noon.
1	29·373	29·314	29·225	29·193	52·7	48·6	N	1	29·569	29·494	29·363	29·244	49·4	48·0	NE
2	29·180	29·178	29·186	29·256	51·3	41·9	W	2	29·160	29·137	29·007	28·946	50·2	47·9	NE
3	29·263	29·327	29·367	29·393	53·0	40·4	SSW	3	29·058	29·272	29·343	29·377	50·2	44·4	SE
4	29·362	29·279	29·089	28·939	48·4	41·0	ESE	4	29·355	29·489	29·457	29·393	50·2	41·2	NE
5	29·278	29·518	29·620	29·718	52·9	35·4	SW	5	29·388	29·445	29·485	29·546	49·1	41·1	N
6	29·719	29·681	29·504	29·316	51·3	33·2	NNE	6	29·587	29·663	29·682	29·732	44·4	36·8	NNW
7	29·318	29·383	29·416	29·419	53·5	47·3	SE	7	29·701	29·696	29·656	29·672	50·4	35·2	NNE
8	29·344	29·299	29·244	29·295	52·0	49·2	N	8	29·687	29·729	29·786	29·852	50·0	44·3	NNE
9	29·398	29·502	29·755	29·917	53·0	46·0	NNE	9	29·902	30·034	30·105	30·231	46·3	39·4	NNE
10	30·022	30·199	30·291	30·422	49·8	41·4	NE	10	30·300	30·380	30·414	30·430	42·6	35·0	N
11	30·448	30·504	30·472	30·488	47·7	31·6	NNE	11	30·420	30·417	30·410	30·400	45·6	37·4	WSW
12	30·482	30·486	30·440	30·453	45·4	29·4	NNE	12	30·379	30·397	30·376	30·378	46·2	43·1	SW
13	30·445	30·458	30·407	30·410	42·0	32·1	NNE	13	30·370	30·357	30·298	30·261	46·4	39·4	SW
14	30·369	30·353	30·261	30·203	47·0	39·3	E	14	30·173	30·073	29·908	29·836	48·3	42·2	S
15	30·077	30·006	29·657	29·709	50·7	40·0	SW	15	29·778	29·596	29·563	29·704	47·0	39·2	SSE
16	29·881	29·878	29·522	29·500	53·1	40·5	SW	16	29·678	29·559	29·310	29·248	42·6	38·5	SE
17	29·484	29·394	29·306	29·394	52·2	43·6	SW	17	29·098	28·939	28·869	28·946	46·2	38·1	SW
18	29·294	29·157	29·054	29·112	46·7	34·4	SSW	18	28·963	28·954	28·937	28·952	41·7	33·2	SW
19	29·125	29·175	29·225	29·330	42·7	29·7	SW	19	28·955	28·977	29·022	29·136	42·1	34·2	WNW
20	29·441	29·623	29·737	29·775	44·1	37·1	WNW	20	29·198	29·350	29·468	29·507	43·4	37·8	W
21	29·632	29·680	29·863	30·009	56·0	41·3	W	21	29·469	29·558	29·622	29·604	45·3	38·5	E
22	30·153	30·299	30·370	30·485	59·0	49·5	SW	22	29·676	29·822	29·915	30·045	57·3	44·8	SW
23	30·484	30·536	30·513	30·515	54·9	44·9	SW	23	30·087	30·129	30·142	30·205	56·7	54·1	SW
24	30·517	30·536	30·514	30·527	51·8	47·4	SSW	24	30·182	30·189	30·206	30·281	56·5	50·0	SSW
25	30·503	30·509	30·500	30·521	50·1	44·6	W	25	30·272	30·279	30·315	30·356	53·2	50·7	SW
26	30·501	30·463	30·367	30·265	50·4	40·9	SW	26	30·280	30·169	30·065	29·928	53·0	48·3	SW
27	30·057	30·012	30·079	30·165	56·0	43·6	NW	27	29·813	29·878	29·949	29·989	50·0	45·9	W
28	30·199	30·189	30·149	30·157	52·3	39·5	SW	28	29·896	29·822	29·797	29·747	53·4	46·2	WSW
29	30·120	30·167	30·101	29·992	55·3	50·9	WSW	29	29·707	29·803	29·590	29·345	55·9	46·3	SW
30	29·873	29·822	29·811	29·848	55·4	40·0	NW	30	29·563	29·614	29·599	29·616	58·0	37·8	W

DECEMBER, 1906.

1	29·816	29·977	30·143	30·274	45·5	34·9	NW	1	29·823	30·036	30·113	30·050	42·1	37·2	W
2	30·294	30·172	30·098	30·110	52·0	34·3	SW	2	29·782	29·771	29·765	29·680	52·4	38·7	WSW
3	30·006	29·912	29·958	30·011	55·0	47·2	W	3	29·576	29·551	29·602	29·801	53·1	42·6	W
4	30·042	30·059	30·020	29·926	54·0	47·2	W	4	29·857	29·880	29·696	29·566	52·4	43·9	W
5	29·735	29·580	29·401	29·242	53·1	40·3	WNW	5	29·402	29·199	28·906	29·454	49·0	36·1	WSW
6	29·485	29·812	29·973	30·179	46·5	38·6	N	6	29·792	30·104	30·249	30·324	44·6	36·1	N
7	30·281	30·379	30·349	30·325	41·7	30·2	N	7	30·281	30·223	30·082	29·968	46·1	34·9	SW
8	30·228	30·094	29·883	29·749	44·5	30·0	SW	8	29·824	29·739	29·564	29·483	47·8	36·0	WSW
9	29·605	29·636	29·705	29·764	43·6	32·6	NNW	9	29·486	29·683	29·742	29·817	37·7	32·2	W
10	29·791	29·864	29·875	29·893	36·5	28·2	NW	10	29·854	29·890	29·839	29·786	35·3	30·5	W
11	29·849	29·843	29·774	29·680	45·1	27·4	WSW	11	29·674	29·616	29·573	29·486	39·1	33·4	WSW
12	29·602	29·445	29·481	29·623	45·1	37·0	WSW	12	29·250	29·145	29·214	29·364	41·4	33·6	N
13	29·677	29·548	29·451	29·462	39·3	33·3	SW	13	29·360	29·263	29·284	29·287	38·0	31·9	W
14	29·432	29·572	29·714	29·849	40·4	33·4	WNW	14	29·298	29·476	29·666	29·795	37·4	31·7	W
15	29·949	30·038	30·068	30·111	38·0	32·6	SW	15	29·843	29·898	29·903	29·895	36·6	27·1	W
16	30·124	30·149	30·181	30·268	44·4	35·0	S	16	29·835	29·916	29·988	30·066	50·0	34·0	E
17	30·312	30·372	30·366	30·372	48·0	42·8	S	17	30·093	30·136	30·129	30·139	50·7	46·7	SW
18	30·343	30·366	30·366	30·420	49·1	43·5	SW	18	30·170	30·228	30·268	30·297	50·8	47·3	SW
19	30·454	30·523	30·517	30·557	45·1	38·4	ESE	19	30·290	30·316	30·318	30·369	48·4	46·0	SW
20	30·595	30·611	30·585	30·573	40·3	35·0	E	20	30·407	30·438	30·450	30·498	48·2	43·4	SW
21	30·555	30·566	30·549	30·544	40·1	31·9	ENE	21	30·508	30·554	30·542	30·528	45·6	43·3	SW
22	30·467	30·437	30·331	30·343	37·8	29·3	NE	22	30·508	30·499	30·390	30·316	44·0	36·0	SW
23	30·320	30·341	30·317	30·358	30·8	27·4	NW	23	30·248	30·202	30·115	30·098	41·7	36·3	SW
24	30·305	30·251	30·054	29·838	42·7	25·7	W	24	30·049	29·927	29·652	29·828	44·2	33·9	SW
25	29·857	29·910	29·843	29·688	42·4	30·8	NW	25	29·860	29·878	29·716	29·487	35·0	26·2	NW
26	29·069	28·957	29·122	29·168	35·2	23·3	N	26	29·304	29·280	29·022	29·175	34·3	21·8	W
27	29·127	29·279	29·351	29·368	35·0	24·5	NW	27	29·263	29·283	29·319	29·451	34·5	28·6	W
28	29·359	29·422	29·411	29·493	35·7	27·9	W	28	29·492	29·623	29·724	29·846	34·7	30·3	N
29	29·621	29·757	29·812	29·841	36·0	28·0	N	29	29·853	29·823	29·751	29·711	33·4	23·9	NW
30	29·784	29·784	29·684	29·582	35·3	26·4	S	30	29·636	29·565	29·437	29·452	30·6	23·4	NE
31	29·531	29·567	29·495	29·519	41·3	34·5	SW	31	29·437	29·368	29·158	29·193	37·4	28·5	ENE

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N. S.—The North Staffordshire Institute of Mining and Mechanical Engineers.
S. I.—The Mining Institute of Scotland.
S. S.—The South Staffordshire and Warwickshire Institute of Mining Engineers.

A.

Aasvogelrand, South Africa, quartzites, dip of, 548.
ABEL, SIR FREDERICK A., quoted, 308, 326.
ABELL, W PRICE, *improvements required in inland navigation*, 364.
Abolesheff bay, eastern Siberia, pyrites lodes, 719.
Accidents, fatal, coal and gas outbursts, 313.
—, —, — output and, 332.
Accounts, S.I., 154.
Accumulators, Pollak, electric power-station, Grand Hornu, 653.
ACKROYD, ALFRED, election, M.G., 290.
Adalia, Asia Minor, chrome-iron-ore, 710.
Adana, Asia Minor, chrome-iron-ore, 710.
Address, presidential, 330.
Advance bore-holes, precaution against coal and gas outbursts, 317.
Aerolith, liquid air rescue-apparatus, 170.
AGNEW electric drill, Gay Coal and Coke Company, 564.
AHNERT, E., gold-bearing regions of Siberia, 714.
AHNERT, E., M. M. IVANOFF, A. KHLAPONIN, P. RIPPAS and P. YAVOROVSKY, gold-bearing regions of Siberia, 714.
Air, liquid, use in rescue-apparatus, 2, 170.
Air-compression, adiabatic, advantages, 445.
Air-compressors, air-lift pumps, 495.
— —, electrically-driven, 501.
— —, — —, economies effected by, 338.
— —, inbye, advantages, 445.
Air-currents, measuring velocities of, 58 *et seq.*
Air-lift pumps, 492.
— — —, efficiency, 498, 499.
— — —, limitations, 493.
— — —, water-supplies from bore-holes, 485.
Akmolinsk, Siberia, coal-fields, 526.
Alaska, coal-fields, Manchurian coal-fields and, 712.
Albion colliery explosion, cause, 185.
Aldan river, Siberia, gold-placers, 715.
ALDIS, W. STEADMAN, quoted, 568, 586, 625, 631.
Alexandretta, Asia Minor, chrome-iron-ore, 710.
Alghero, Sardinia, copper-ores, 685.
ALISON, M. S., quoted, 553.
ALLERTON, LORD, quoted, 29.
Almeria, Spain, ore-deposits, 699.
Alps, Piedmontese, graphite-deposits, 683.
—, South Africa and, structural geology compared, 552.
Altofts collieries, experimental gallery, 205.
— —, — —, pneumatogen trial at, 251.
— —, — —, report on rescue-work, 209.
— —, explosion, 279.

Amalgam, gold, native, Servia, 696.
Amasra, Asia Minor, coal-fields, 711.
Amgûn river, Siberia, gold-placers, 715, 716.
Ammonia, freezing-process, Monkwearmouth, 276.
—, recovery of, coking-plant, Clay Cross, 396.
—, — —, from gas-producers, 341.
Ammonia-soda works, Fleetwood, rock-salt utilised in, 293.
Amur, Siberia, gold-placers, 715.
Analyses, coal, Polmaise collieries, 239.
—, — and fire-clay, Siberia, Akmolinsk, 526.
—, coke, bye-product, Clay Cross, 394.
—, gypsum, Sussex, 451, 452.
—, magnetic pyrites, 688.
—, schcelite, Sardinia, 687.
Anangra river, Siberia, gold-placers, 715.
Anatolian Railway Company, quoted, 711.
Ancient mining, Asia Minor, 708.
— —, cost of labour and, 708.
Anderson, J., quoted, 233.
Anderson, W., quoted, 546.
André, G. G., quoted, 568, 571, 572, 632.
Anemometers, precautions in using, 58, 62, 64.
Angelina cavern, Servia, Kucajna, auriferous deposits, 696.
Anhydrite, artificial formation of, 457, 458.
—, deposition from sea-water, theory concerning, 458.
—, recovery of sulphur from, 458.
Annual report of council, S.I., 151.
Ansley Hall colliery, coal-seams at, 515.
— — —, method of working, 515.
Anthracite, graphite derived from, Ligurian Alps, 684.
—, Korea, Hpyeng-Yang, 713.
—, Polmaise collieries, 239.
—, — —, sorting plant, 242.
—, — —, washing plant, 243.
Antimony-ores, Asia Minor, 711.
Arghana Madén, Asia Minor, copper-mine, 710.
Arley colliery, coal-measures at, 264.
— —, coal-seams, 272.
Armatures, generators, Park Royal power-station, 636.
Armour, James, election, councillor, S.I., 153.
Armstrong
Tyne, Dag
mining, 20
—, — — —,
Arnold, Th
Arnot, Th
machines,
Arnott, Th
S.I., 153.
Arsenical py
Smyrna, 7
Artesian wel
— —, testin
— —, water
Ashby-de-la-
43.
Ashton cana
Ashworth,
Grange col
Asia Minor,
Askew, Alf
Asphalt-depo
675.
— —, —, —,
with, 676.
Assam, uppe
Assarli, Asia
Associated
facturers
Bevan &
fleet, 642.
—, quoted, 6
Atchley, C
S.I., 153.
Atherton,
posits at P
Atkinson, J
Atkinson, J
Atkinson, W
gas, 320.
—, quoted, 4
Atkinson, W
Courrières
303, 326.
Auditors, xi
Austria, Ga
mine, 535.
Avala hill, S
Avery, W
N.E., 250.
Aznalcollar,
Azufrones or
Azurite, arti
ture requi
—, Sardinia,
—, Spain, A

B.

Babcock-and-Wilcox boilers, efficiency, 338.
— — — —, Park Royal power-station, 639.
Baddeley, H., *guides for cages*, 116.
Baden, Black Forest, nickeliferous magnetic pyrites, 677.
Badger, W
Baggeridge
Baghdad rai
Asia Mino
Bailey, S.,
Bailey, T.
lands, 263.

BAIN, JAMES, election, councillor, S.I., 153.
BAINBRIDGE, EMERSON, *application of duplicate fans to mines*, 437.
—, *notes on bye-product coke-ovens*, 420.
—, *presidential address*, 345.
Balance-ropes, vibration of guide-ropes lessened by, 116.
Balia lead-mine, Asia Minor, 710.
Ball-mills, grinding cement-clinker in, Knight, Bevan & Sturge works, 644.
Bank-gold, placer deposits, Finnish Lapland, 694.
Barberton, South Africa, granite-masses, 541.
BARCLAY, PERKINS & COMPANY, pumping-plant for water-supply, 492.
BARMAN, HARRY D. D., election, councillor, S.I., 153.
—, *tests of a mine-fan*, 59.
Barnsley district, importance of scientific mining in, 90.
BARNSLEY NATURALIST AND SCIENTIFIC SOCIETY, quoted, 102.
Barometer readings for 1906, 725.
BARRACLOUGH coal-washery, coking-plant, Clay Cross, 390.
BARRETT, VICTOR HOLMES MCNAUGHTEN, election, S.S., 261.
Barriers, isolation of districts by, 131, 133.
BARROW HEMATITE STEEL COMPANY, LIMITED, quoted, 209.
Barytes, Norway, Traag, 690.
—, Spain, Almeria, copper-ores associated with, 701.
BATES, THOMAS, election, N.E., 180.
Battle water-works, air-compressor, 495.
BAUER, —, quoted, 680.
BAUMGÄRTEL, B., quoted, 681, 682.
Bavaria, Fichtelgebirge, stanniferous deposits, 679.
BAYNE, J. A. C., election, S.I., 236.
BEALES, HENRY BATSON, election, M.G., 170.
Beams, ferro-concrete, construction, 10.
—, stresses in, 11.
BEAUMONT, W. WORBY, *improvements required in inland navigation*, 373.
BECK, R., quoted, 681.
—, tungsten-ore deposits in Saxony, 682.
Bédar, Spain, iron-ores, 699.
Bedford, canals for drainage purposes, 354.
BEDFORD LEVEL CORPORATION, quoted, 354, 355.
BEDSON, P. PHILLIPS, quoted, 184.
Bedworth colliery, thickness of coal at, 263.
Beehive coke-ovens, Clay Cross, 386.
BEKENN, ALEXANDER RICHARD, election, N.E., 1.
Bela-Reka, Servia, sulphide-ores, 696.
Belgium, coal-fields, Siberian coal-fields compared with, 713.
Belgium, depth of coal-workings, 266.
—, Grand Hornu, electric transmission of power at works and collieries, 647.
Believina, Servia, sulphide-ores, 696.
BELK, WILLIAM JAMES, election, M.I., 208.
BELL, SIR LOWTHIAN, BART., memoir, 665.
—, quoted, 428.
BELL BROTHERS, establishing of firm, 665.
BELLISS-AND-MORCOM engines, electric power-station, Knight, Bevan and Sturge cement works, 646.
— — — —, — — —, Park Royal, 636.
Bembridge, Isle of Wight, air-lift pumping in bore-hole for water-supply, 486.
Bender Eregli, Asia Minor, coal-fields, 711.
BENTLEY, JOHN, election, N.S., 76.
Bering Straits, geology, 720.
BERTEAUX, —, mineral resources of Korea, 712.
BERTHELOT-MAHLER calorimeter, 285.
Birmingham coal-field, extensions, 44.
Bizerta, Tunis, ferro-concrete buildings, subsidence of, 15.
BLACK, JAMES, *tests of a mine-fan*, 63, 155.
Black Forest, Baden, nickeliferous magnetic pyrites, 677.
BLACKETT, W. C., *explosion at Wingate Grange colliery*, 188.
—, *new apparatus for rescue-work in mines*, 180.
Blackwell colliery explosion, cause, 128.
BLAKE, JOHN, *heading by longwall machines*, 159.
Blast-furnaces, bye-product coke for, 342.
— —, — — — —, Clay Cross, 394.
BLUNDEN, PHILIP SIDNEY, election, N.E., 250.
BLYTH, ARCHIBALD, election, vice-president, S.I., 153.
BOARD OF TRADE, quoted, 353, 366, 377, 379, 584, 587.
BODART, —, quoted, 618.
BOGDANOVICH, —, quoted, 719.
Boiler-ashes, disposal of, electric power-station, Grand Hornu, 650.
— —, — —, — — —, Park Royal, 642.
Boiler-flues, Babcock and Wilcox boilers, Park Royal power-station, 640.
Boilers, Babcock and Wilcox, Park Royal power-station, 639.
—, — — — and Lancashire, comparison, 338.
—, colliery, improvements in, 338.
—, corrosion, temperature-factor, 577.
—, electric power-plant, Boryslaw, ozokerite-mine, 536.
—, feed-water for, distillation of, 463.
—, Lancashire, coking-plant, Clay Cross, 388.
—, —, Polmaise collieries, 239, 245.

Boilers, Perkins, Sub-Wealden Gypsum Company, Limited, 461.
—, semi-tubular, electric power-station, Grand Hornu, 649.
—, strength of, 583.
— for colliery purposes.—Discussion, 167.
Bolton, H. Hargreaves, Jun., election, M.G., 277.
Bonthron, P., *improvements required in inland navigation*, 369.
Bor, Servia, gold associated with chalcopyrite, 697.
Bore-holes, advance, precautions against coal and gas outbursts, 317.
Boring, artesian wells, 475 *et seq.*
—, methods available, 480.
—, shot-drilling method, 482, 497 *et seq.*
— appliances, bore-holes, freezing-process, Monkwearmouth, 275.
Boryslaw, Austria, Galicia, ozokerite-mine, 535.
Bosworth, —, quoted, 449.
Bottom-gold, placer-deposits, Finnish Lapland, 694.
Boyd, Edward Fenwick, quoted, 201.
Boyd, John Black, election, S.I., 52.
Brace, James H., *sinking by freezing-process*, 197.
Bradshaw's canals and navigable rivers of England and Wales, quoted, 347.
Brakes, electric winding-engines, Grand Hornu colliery, 660.
Brancepeth colliery, coal-dust treatment, 254.
— — explosion, report on, 189.
Brandenburg, Prussia, brown-coal deposits, 673.
Bricking, shafts, Preesall salt-mine, 293.
Bridges, ferro-concrete applied to construction of, 17 *et seq.*
Brine, pumping of, Preesall, 293, 301.
Briquette-factories, brown-coal, upper Lausitz, 674, 675.
Briquetting, utilization of small coal by, 138.
Bristol Docks Committee, quoted, 375.
British Bechuanaland, South Africa, geology, 547.
Broadhurst, Herbert F., water-supplies by means of artesian bored tube-wells, 473.—Discussion, 497.
Brough, Bennett H., quoted, 3.
Brown, Adam, election, councillor, S.I., 153.
Brown, John, election, N.E., 250.
Brown, John F. K., stretcher for use in mines, 162.
Brown, M. Walton, *Courrières explosion*, 310.
—, memoir of the late John Daglish, 201.
—, *pneumatogen*, 250.
—, *sinking by freezing process*, 252.
Brown-coal, Asia Minor, 711.
— — deposits, Silesia, upper Lausitz, 673.
Browne, J. T., thick coal of Warwickshire, 502.—Discussion, 513.
Browney colliery, coal-dust treatment, 254.
Bruce, John Collingwood, quoted, 201.
Brussa, Asia Minor, antimony-ores, 711.
—, — —, chrome-iron-ore deposits, 710.
—, — —, meerschaum deposits, 709.
Bryan-Donkin calorimeter, 286.
Buckley, F. E., *gob-fire in Shropshire mine*, 85.
—, outbursts of coal and gas in Cockshead seam, Shelton colliery, 313.—Discussion, 320.
Buildings, ferro-concrete, 12 *et seq.*
—, foundations for, application of ferro-concrete, 13.
Bulbuderé, Asia Minor, copper-mine, 711.
Bumps, Warwickshire collieries, 529.
Burnham water-works, air-pumping plant, 495.
Burns, David, *gypsum in Sussex*, 471.
Burnside boring-machine, Shelton colliery, 317.
Bushveld, South Africa, folding of strata, 544.
—, — —, — — —, theory, 542.
Buttgenbach, H., copper, tin, and gold in Katanga, Congo Free State, 721.
Bye-laws, xii.
Bye-product coke-ovens, adoption of, 342.
— — — —, Clay Cross, 386.
— — — —, notes on, with special reference to Koppers oven, 398.—Discussion, 416.
Bye-products from coke-ovens, possible diminution in value, 421.
— — — — —, yield per ton of coal coked, Clay Cross, 396.
— — — gas-producers, recovery of, 341.

C.

Cabezas del Pasto copper-mine, Spain, Huelva, 706.
Cable railway, Spain, Almeria, 702.
Cables, electric power-station, Grand Hornu, 648, 655.
—, — — —, Park Royal, 634.
Cadeby colliery, steel-rail guides at, 114.
Cadlimo, Switzerland, silver-bearing galena, 707.
Cadman, James Cope, *notes on bye-product coke-ovens*, 416.
—, *outbursts of coal and gas*, 320.
Cage-guardian, Hanley, 164, 168.
Cage-lowering tables at New Moss colliery, 174.—Discussion, 177.
Cages, guides for, deep shafts, 104, 108.
—, Polmaise collieries, 240.

Cagliari, Italy, Sardinia, tungsten-ores, 686.
Calabria, Italy, Olivadi graphite-mine, 685.
Caldwell, James, quoted, 53.
Calomel, native, Servia, 698.
Calorific value, coals, Polmaise collieries, 239.
— —, methods available for determining, 284.
— —, new form of bomb for determination of, 283.
— —, precautions in determining, 287.
— — as a test for fuels, 287, 288, 289.
Calorimeters, principle of various forms, 285.
Calorimetric bomb, Cook, 283.
Cambridge, university of, quoted, 331.
— water-works, water-supply from tube-well, 499.
Camerton colliery explosion, cause, 128, 133, 184.
Canal-boats, conveyance by pontoons, 377.
— —, narrow, difficulties with, 358.
Canals, Birmingham district, costs, 376.
—, connecting manufacturing towns, desirability, 349.
—, decline of, reasons, 370.
—, financial difficulties in suggested improvements, 381.
—, form of section, 368.
—, frost and, 371.
—, improvements required in, 347.
—, — — —, methods suggested, 355.
—, maintenance for drainage purposes, 354.
—, mechanical haulage on, 360, 365, 373.
—, — — —, internal-combustion engines, 362, 373, 382.
—, nationalization, 364, 379, 382.
—, water-supply for, 383.
Cannock Chase coal-field, colliery fuel-consumption, 168.
— — — —, extensions, 44, 45, 46.
— — — —, faults, 266.
Cantrill, Thomas Crosbee, quoted, 28.
Cape Colony, folding of strata, 544.
— Nome gold-placers, eastern Siberia, 719.
Capell, G. M., application of duplicate fans to mines, 431.—Discussion, 433.
Capell fans, electrically-driven, Grand Hornu colliery, 662.
— —, Neumühl colliery, water-gauge, 344.
— —, Polmaise collieries, 246.
— —, tests, 58.
Capels for winding-ropes, 343.
Carbon dioxide, from gob-fire, Shropshire, 79.
— —, respiratory phenomena, 214, 222.
— —, test for, 221.
— monoxide, deaths from, after explosions, 6.
Carbon monoxide, pneumonia and, 6.
— —, respiration in, acclimatization to, 7.
— —, — —, effects produced, 6, 7.
Carey, Arthur, *improvements required in inland navigation*, 372.
Carolina, South Africa, pans, 555.
Carpio copper-mine, Spain, Huelva, 705.
Carr disintegrator, coal-crushing, Clay Cross, 388.
Cassiterite, Congo Free State, 722.
—, wolfram associated with, Saxony, 683.
Cast-iron, effects of mine-waters on, 575 *et seq.*
— — tubbing, what is its rational formula? 567.—Discussion, 617, 664.
Castello di Bonvei, Italy, Sardinia, azurite-deposit, 685.
Cement, sealing-off objectionable water-supplies with, 478.
—, setting of, action of moisture and, 645.
—, — —, fineness of grinding and, 645.
Cement-concrete, back-lining of tubbing with, 579.
— —, properties, 10.
Cement manufacture, chemistry of, 643.
— works, Knight, Bevan & Sturge, Kent, Northfleet, 642.
Census of production act, quoted, 334.
Central Electric Company, St. John's Wood, air-lift pump, 499.
Central Rand, folding of strata, 544.
Chain-breast machines, driving headings with, 67.
Chalcopyrite, Baden, Horbach mine, 677.
—, Servia, gold associated with, 696.
—, Sicily, 688.
—, Spain, Huelva, 705.
Chalk, use in cement manufacture, Knight, Bevan & Sturge works, 642.
Chalybite, Spain, Almeria, associated with galena, 703.
Chambers, D. M., ozokerite (mineral-wax) mine of Galizische Kreditbank, at Boryslaw, Galicia, Austria, 535.
Chambers, J. E., quoted, 209.
Chance sulphur-recovery process, 458.
Channelling machines, driving headings with, 66.
Chapman, John Abel, election, N.E., 249.
Chartley, keuper marls at, 42.
Chatham, tube-well at, 479.
Chaudron, —, quoted, 625, 626, 632.
Chernoistochinsky works, Nizhne-Tagilsk, 695.
Cheshire coal-field, extensions, 40.
Cheshire Conference on Railway and Canal Rates, quoted, 378.
Chessylite or azurite, Italy, Sardinia, 685.
Chimneys, Polmaise collieries, 239, 245.
China, southern Manchuria, Fushun, coal-fields, 712.

Chisone, Italy, graphite-deposits, 684.
Christie, E. J. H., election, M.C., 120.
Chrome-iron-ore, Asia Minor, 710.
— — —, — —, output, 710.
Chromiferous potash-mica, Servia, 697.
Chrysocolla, Congo Free State, 721.
Chukchen peninsula, eastern Siberia, mineral resources, 719.
Chuniespoort, South Africa, folding of strata, 544.
Cinnabar, Asia Minor, 710.
— and associated minerals, Servia, 698.
Clarence ironworks, establishing of, 665.
Clark, W. F., *hidden coal-fields of Midlands*, 50.
Clarke, W. J., quoted, 33, 272.
Claude system, liquid air manufacture, cost, 2.
Claughton, G. H., *hidden coal-fields of Midlands*, 50.
Claverley bore-hole, 265.
— — —, Staffordshire and Coalbrookdale coal-field extensions and, 47.
Clay, use in cement manufacture, Knight, Bevan & Sturge works, 642.
Clay Cross, bye-product coking-plant, 386.
Cleveland ironstone beds, discovery of, 665.
— — —, phosphorus in, difficulties due to, 666.
Clifford, W. quoted, 233.
Clifton and Kersley collieries, cage-discharging devices, 177.
Clive, Robert, *application of duplicate fans to mines*, 433.
Clyde Trust, quoted, 55.
Clydebank dock, electric power-plant, flywheel running in vacuum, 55.
Coal, analyses, Polmaise collieries, 239.
—, —, Siberia, Akmolinsk, 526.
—, analysis, sampling for, 283.
—, crushing of, gob-fires caused by, 504, 521.
—, fine, treatment in Elliott washer, 143, 144.
—, inferior, utilization in gas-power plants, 341.
—, powdered, fuel for cement kilns, 643.
—, quality of, underground fire, Freehold colliery, 83, 84.
—, selling-price and thickness of seams workable, 101.
—, small, increasing value of, 138.
— and gas outbursts, Shelton colliery, 313.
Coal-crushing plant, Clay Cross, 388.
Coal-cutting, mechanical, in headings and longwall workings, comparison, 73.
— —, —, problems of, 445.
— — machines, bar type, American and British compared, 67.
— — —, economies effected by, 337.
— — —, electric, Gay Coal and Coke Company, 559, 563.
Coal-cutting machines, filling of coal and rate of advance, 71.
— — —, longwall, heading by, 65, 155.
— — —, performance of, 67, 68, 69.
— — —, stable-holes and, 158.
— — —, thin seams and, 93.
— — —, turn-tables for, 159, 160.
Coal-dust, collieries, United Kingdom and continental countries compared, 130.
— —, Courrières collieries, characteristics, 127.
— —, — —, quantity, 304.
— —, explosions and, 309, 333.
— —, haulage-roads, character of, 258.
— —, — —, increased danger from, 128.
— —, removal from mines, 187, 188, 190, 192, 195, 196.
— —, — — —, by brushing, dangers, 259.
— —, — — —, — suction-appliances, 259, 311.
— —, screens, 344.
— —, steam and, 193.
— —, treatment of, aboveground and belowground, 254.
— —, tub-grease and, 259.
— —, tubs and, 192.
— —, utilization as fuel, 339.
— —, ventilation and, 183, 184, 185.
— —, Wingate Grange colliery, analyses, 195.
— — explosions, high explosives and, 310.
— — —, prevention of, 127.
— — —, propagation of, effects of air-splitting, 124.
— — —, United Kingdom, 1906, summary, 725.
— — —, Wingate Grange colliery, 183.
Coal-face, conveyors for, sliding-trough, 198.
— —, — —, thin seams, 94 *et seq.*
— —, hauling arrangements at, 663.
Coal-fields, Asia Minor, 711.
— —, brown, Silesia, upper Lausitz, 673.
— —, extensions limited by depth of seams, 37, 38.
— —, Kent, discovery of, 470.
— —, Korea, 713.
— —, Midlands, anticlinal divisions, 35.
— —, —, area of, 37.
— —, —, hidden, 26.—Discussion, 50, 261.
— —, —, —, depth of seams, 49.
— —, —, —, estimated areas, 49.
— —, —, theory of origin, 34.
— —, Siberia, Akmolinsk, 526.
— —, —, Kuznetsk, 713.
— —, south Yorkshire, Barnsley, workable seams, 92.
— —, southern Manchuria, Fushun, 712.
— —, Warwickshire, thick coal-seam, 502.

Coal-handling plant, electric power-station, Grand Hornu, 649.
— — —, — — —, Park Royal, 641.
Coal-measures, upper Silesia, posidonia becheri in, 675.
Coal-measuring boxes, Klein, Park Royal power-station, 642.
Coal-mines (eight hours) bill, quoted, 335.
— — regulation act. quoted, 335.
Coal-mining, death-rate per 1,000, United Kingdom, 334.
Coal output, Asia Minor, Heraklea mine, 711.
— —, labour employed and, West Virginia, 564.
— — and fatal accidents, 332.
Coal-seams, working of, thick and thin, comparison, 90 *et seq.*
Coal-washers, theory of action, 138, 141 *et seq.*
Coal-washing, sizing of coal, 141 *et seq.*
— —, water required, trough-washers, 147.
Coal-washing-plant, Barraclough, Clay Cross, 390.
— — —, Polmaise collieries, 242, 247.
Coalbrookdale coal-field, extensions, 47.
— — —, strata, 33.
Cockin, George M., *hidden coal-fields of Midlands*, 268.
Coke, G. Elmsley, *sinking and tubbing at Methley Junction colliery*, 120.
—, *water-supplies by tube-wells*, 498.
Coke, bye-product, use in blast-furnaces, 342.
—, Clay Cross, analyses, 394.
—, — —, output, 393.
—, — —, quenching, 392.
Coke-oven flues, bye-product coke-ovens, Clay Cross, 387.
— — —, types compared, 399.
— — gases, Clay Cross, treatment of, 392.
— — —, — —, use for illumination, 397.
— — —, Koppers oven, 412.
— — —, regenerators and, 401.
— — —, surplus, utilization of, 342.
Coke-ovens, beehive, Clay Cross, 386.
— —, — and bye-product, commercial considerations, 418.
— —, bye-product, adoption of, 342.
— —, — —, Clay Cross, 386.
— —, — —, — —, coal-compressing plant, 390.
— —, — —, — —, compressed coal for charging, 387.
— —, — —, — —, course of gases in, 393.
— —, — —, combustion, regulation of, 416.
— —, — —, commercial results from, 426.
— —, — —, essential differences in various types, 398.
— —, — —, fire-bricks for, 420, 426.
Coke-ovens, bye-product, heat lost by radiation, 400.
— —, — —, horizontal and vertical flues compared, 418 *et seq.*
— —, — —, Koppers, 398.
— —, — —, —, course of gases in, 403.
— —, — —, —, regenerator, 407.
— —, — —, —, —, automatic reversing-gear, 410.
— —, — —, life of, 419, 421.
— —, — —, partition walls of, 417, 419, 422 *et seq.*
— —, — —, pre-heating of air for, 401.
— —, — —, regenerators for, reasons for adoption, 401.
— —, — —, regulation of working, 401.
— —, — —, supporting walls, effect of temperature on, 410.
— —, capital invested in, 418.
Coleman, W. H., Cook calorimetric bomb, 283.—Discussion, 288.
Collieries, Belgium, Grand Hornu, electric transmission of power, 647.
Colliery boilers, 167.
Commandonek, South Africa, monticule at, 551.
Compressed-air, Preesall salt-mine, 297.
— —, — — —, tunnelling-machine, 294.
Concrete, effect on iron embedded in, 22.
—, resistance to strains, 10.
Condensing plant, electric power-station, Grand Hornu, 651, 655.
— —, — — —, Park Royal, 638.
Conglomerates, gold-bearing, South Africa, Rand, 532.
Congo Free State, Katanga, copper, tin and gold deposits, 721.
Contact-metamorphism, graphite-deposits, Piedmontese Alps, 684.
— —, manganese ore-deposits, 695.
— —, nickeliferous magnetic pyrites, Baden, 678.
Conveyors, coal, Park Royal power-station, 641.
— at coal-face, adoption of, 338.
— — — —, gateways, spacing of, 94.
— — — —, hand-cut faces, 95.
— — — —, machine-cutting and, 72.
— — — —, sliding-trough, 198.
— — — —, sorting of coal in using, 94.
— — — —, thin seams and, 93.
Cook calorimetric bomb, 283.—Discussion, 288.
Cooling towers, condensing plant, electric power-station, Grand Hornu, 656.
Cooper, James, election, S.I., 153.
Cooper-Hewitt mercury-vapour lamps, 297.
Coppée, Evence, election, N.E., 1.
Copper-ores, Asia Minor, 710.
— —, — —, output, 711.
— —, Congo Free State, Katanga, 721.
— —, Italy, Sardinia, 685.
— —, —, —, comparison with French and Hungarian deposits, 686.

Copper-ores, Korea, 713.
— —, Prussia, Hesse-Nassau, 680.
— —, Sicily, 680.
— —, Spain, Almeria, 699.
— —, —, —, output, 701.
— —, —, Huelva, 704.
— —, —, —, enrichment, 706.
Copper pyrites, Saxony, western Erzgebirge, 681.
CORDIER, —, quoted, 310.
CORNET, J., quoted, 721.
Cornish pumping-engines, fuel consumption, 342.
Corrosion of cast-iron tubbing, 570 *et seq.*
— — — — — —, electrical phenomena of, 578.
— — — — — —, measurement of, data for, 579.
Corundum, Asia Minor, 710.
—, — —, output, 710.
Corweiler, Prussia, metalliferous belt, 680.
Cos, Asia Minor, copper-mine, 711.
Coscojares, Spain, ore-deposits, 701.
Cottian Alps, graphite-deposits, 684.
COULSON, F., *sinking by freezing process*, 251.
—, *treatment of dust in mines*, 259.
—, *water-supplies by tube-wells*, 497.
Council, election, S.I., 153.
Councillors, list, x.
Council's annual report, S.I., 151.
Courrières explosion.—Discussion, 124, 303, 326.
— —, cause, 125 *et seq.*, 135, 136, 310.
— —, dead bodies, putrefaction of, 6.
— —, Giersberg-Shamrock rescue-apparatus at, 215.
Courrières explosion, rescue-apparatus at, 182, 280.
— —, — — —, death of a wearer, 3, 228, 232.
— —, rescue-work at, 4, 212.
COWLISHAW, W. G., *Courrières explosion*, 307.
CRAWFORD, ROBERT H., election, S.I., 236.
CREDNER, H., quoted, 673.
CREMER, R., pneumatogen: self-generating rescue-apparatus, compared with other types.—Discussion, 250.
—, quoted, 212.
Crna-Reka gold-fields, Servia, 697.
Crnajka gold-fields, Servia, 697.
CROFTON, C. A., *explosion at Wingate Grange colliery*, 192.
—, *sliding-trough conveyors*, 200.
CROMBIE, R., quoted, 195.
CROMBIE, SIMPSON, election, N.E., 179.
CROUDACE, FRANCIS HENRY LAMBTON, election, N.E., 249.
CROUDACE, SYDNEY, election, N.E., 249.
Crushing-rolls, anthracite coal, Polmaise collieries, 243.
Cruzadillo copper-mine, Spain, Huelva, 705.
Cuchichon copper-mine, Spain, Huelva, 706.
Cuña de esteril or barren shale, 705.
CUNYNGHAME, H., quoted, 310.
Cupriferous magnetic pyrites, Sicily, 688.
Cylinders, thin, calculation of thickness of tubbing and, 569.
—, —, definition, 594.
— subject to pressures, formula for calculating thickness, 611.

D.

Dachsenhausen, Prussia, metalliferous belt, 680.
Daghhardy, Asia Minor, chrome-iron-ore, 710.
DAGLISH, JOHN, memoir, 201.
DALGLEISH, JAMES, election, S.I., 236.
Dam, cast-iron, Methley Junction colliery, 120.
Damaraland, South Africa, geology, 547.
DARLING calorimeter, 285.
Dartford, tube-well at, 479.
DARTMOUTH, EARL OF, quoted, 263.
DAVIDSON, ALLAN ARTHUR, election, N.E., 179.
DAVIDSON, WILLIAM, election, S.I., 236.
DAVIES, W. H., death of, 76.
DAVIS, W. A., quoted, 456.
Dawdon colliery, sinking, freezing-process, 197, 251.
DAWKINS, W. BOYD, *rock-salt deposits at Preesall*, 299.
DE LA BECHE, SIR HENRY, quoted, 278.
DE MORGUES, —, quoted, 310.
DE RANCE, C. E., quoted, 292.
DE SALIS, HENRY RODOLPH, improvements required in inland navigation, 347.—Discussion, 363.
DEACON, M., *Courrières explosion*, 133.
—, *electric winding for main shafts*, 150.
—, *improvements required in inland navigation*, 363.
—, portrait, *frontispiece*.
—, presidential address, 330.
—, quoted, 567.
—, *thick coal of Warwickshire*, 528.
Dean Lane colliery, cage-guardian tests at, 164.
Death-rate per 1,000, various occupations, list, 334.
Decking-cages, hydraulic, cage-lowering tables and, 177.
Deep mining, extent of royalties, 343.
— —, limits, 266.
Deertrail, U.S.A., wolframite, 683.
Deli-Iovan, Servia, gold-mines, 696.
Denbigh coal-field, extensions, 40.

Denbigh coal-measures, thickness, 32.
Denizly, Asia Minor, chrome-iron-ore, 710.
DENNY, G. A., *New Rand gold-field*, 533.
Depth-indicators, electric winding-engines, Grand Hornu colliery, 660.
Derbyshire, south, main coal-seam, precautions against fires, 514.
Dess river, Siberia, gold-placer-deposits, 714.
DEVIL disintegrator for grinding coal, 148.
DEWAR, SIR JAMES, quoted, 2.
Diamond boring, 481.
DIAMOND ROCK-BORING COMPANY, quoted, 449.
DICK, WILLIAM, election, N.E., 179.
DICKINSON, JOSEPH, *new apparatus for rescue-work in mines*, 278.
—, *rock-salt deposits at Preesall*, 298.
DIESEL internal-combustion engines for mechanical haulage on canals, 382.
Disintegrator, Devil, for coal, 148.
DIXON, J. S., quoted, 57.
DORKING GREY STONE LIME COMPANY, quoted, 449.
DRÆGER rescue-apparatus, cleaning of, 218.
— — —, efficiency, 225.
DRÆGER rescue-apparatus, Tankersley rescue-station, 215.
— — —, trials, 209.
Dredging of canals, 351.
Dressing, ores, Spain, Almeria, 700.
—, ozokerite, Boryslaw, 538.
Drilling, rate of, hand and machine, Preesall salt-mine, 295, 296.
DRON, R. W., *heading by longwall machines*, 157.
—, *tests of a mine-fan*, 63.
Drums, winding-engines, electric, Grand Hornu colliery, 657.
—, — —, Polmaise collieries, 240, 246.
DUNKERTON, ERNEST CHARLES, election, N.E., 1.
Duplicate fans, application to mines, 431.
Dust, non-inflammable, dangers from, 306.
—, — —, explosions and, 308, 326.
Dust-extractor, Hardy, 143.
Dust in mines, treatment of, aboveground and belowground, 254. — Discussion, 257.
Dwelling-houses, collieries, improvements, 344, 345.
— —, Polmaise collieries, 244, 248.
Dykes, South Africa, origin of pans and, 554.
Dzwiniacz, Austria, ozokerite, 535.

E.

Earnock colliery, coal-cutting, rate, 159.
ECONOMICAL FIRING COMPANY, Düsseldorf, quoted, 649.
Eddlewood colliery, coal-cutting, rate, 159.
EDELSTEIN, J., quoted, 712.
Education, scientific, advancement, 331.
EDWARDS air-pump, condensing plant, Park Royal power-station, 639.
EGERTON, C. A., quoted, 449.
Ehr, Prussia, metalliferous belt, 680.
Eibenberg, Saxony, copper-mines, 680.
EIGHT HOURS' DAY DEPARTMENTAL COMMITTEE, quoted, 334.
EINECKE, G., Holzappel metalliferous belt, Hesse-Nassau, 680.
Electric cables, breaking of, explosions and, 306.
— coal-cutting machines, flywheel effect in, 447.
— — — —, Gay Coal and Coke Company, 559, 563.
ELECTRIC CONSTRUCTION COMPANY, quoted, 636.
Electric fans, advantages, 438.
— —, difficulties connected with, 432.
— —, reasons for adoption, 437.
— haulage, gypsum mines, Sussex, 468.
— lamps, Preesall salt-mines, 297.
— lighting, current for, 634.
— locomotives, Belgium, Grand Hornu, 647.
Electric power, application to canal boats, 363.
— — at collieries, 336, 337.
— power-plant, Boryslaw, ozokerite-mine, 536.
— — —, Clay Cross, 388.
— — —, Polmaise collieries, 240, 246.
— power-station, Belgium, Grand Hornu, 649.
— — —, Knight, Bevan & Sturge cement works, 646.
— — —, Park Royal, 634.
— — —, — —, auxiliary plant, 636.
— winding, emergency arrangements, Grand Hornu colliery, 653.
— — for main shafts, etc. — Discussion, 150.
— winding-plant, costs, 53.
— — —, Tarbrax, test, 52.
Electrically-driven air-compressors, combined with working of Ingersoll-Sergeant heading-machines, etc. — Discussion, 501.
Electrically-ignited safety-lamps, Polmaise collieries, 241.
Electricity, generation of, efficiency, 57.
Elemore colliery explosion, 193.
ELEY, J. J., *guides for cages*, 115.
—, quoted, 209.
ELLIOTT, C. H., *guides for cages*, 116.
ELLIOTT, GEORGE, election, N.E., 250.
ELLIOTT coal-washer, 138.

ELLIOTT coal-washer, costs of working, 148.
— — —, output, 143.
— drill, Preesall salt-mine, 296.
ELLIOTT'S METAL COMPANY, Birmingham, air-compressor, 495.
—, —, air-lift pump, 498, 499.
Emery-deposits, Asia Minor, 710.
Endless-rope haulage, electric, gypsum-mines, Sussex, 468.
— — —, water-spraying of tubs, 256.
Engines, Belliss-and-Morcom, Park Royal power-station, 636.
—, — — —, — — — —, emergency switch for, 636.
—, electric power-station, Grand Hornu, 650.
—, Perkins high-pressure, 463.
— and boilers (persons in charge) bill, quoted, 335.
ENTREPRISES DE CONSTRUCTIONS DE FOURS À COKE ET D'USINES MÉTALLURGIQUES, quoted, 387.
Equivalent orifice, duplicate fans and, 434, 435, 440.
Ermelo, South Africa, pans, 555.
Erzgebirge, western, Saxony, pyrites-deposits, 680.
Estanque or washing tank, 700.
EVANS & COMPANY, RICHARD, LIMITED, quoted, 339.
Exciters, generators, Park Royal power-station, 636.
Explosions, air-pipes in roadways for use after, 3.
—, coal-dust, panel system of working and, 124.
—, — — and, 254, 333.
—, connection of underground workings and, 129 *et seq.*, 308.
—, Courrières.—Discussion, 124, 303, 326.
—, effect of broken steam-pipes, 192.
—, fire-damp or coal-dust, United Kingdom, summary, 1906, 725.
—, isolation of districts, 306, 309, 310.
—, — — —, iron-doors for, 133.
—, non-inflammable dust and, 326.
—, propagation through moisture-saturated roadways, 194.
—, reports on, criticism of official methods, 189 *et seq.*
—, rescue work and, 279.
—, ventilation after, 222.
—, watering and, 129.
—, Wingate Grange colliery, 304, 305.
—, — — —, absence of after-damp, 193.
—, — — —, discussion on, 183.
Explosives, Courrières explosion and, 303, 304.
—, explosions and, 305.
—, high, coal-dust and, 310.
—, permitted, explosions caused by, 185.
— order, quoted, 128.

F.

FABRY-LINARD coke-ovens, Clay Cross, 390.
Fahlores, Sicily, 688.
FAIRBAIRN, SIR WILLIAM, quoted, 583.
Falls of roof and sides, deaths from, United Kingdom, 333.
Fan-engines, Polmaise collieries, 246.
— —, — —, turbine, 241.
Fan-tests, 58, 155.
Fans, Capell, Neumühl colliery, water-gauge, 344.
—, —, Polmaise collieries, 246.
—, Courrières collieries, not affected by explosion, 307.
—, development of collieries and, 432, 436, 437, 438.
—, duplicate, application to mines, 431.
—, electric, Grand Hornu colliery, 662.
—, Polmaise collieries, 241.
FARADAY, MICHAEL, quoted, 197.
Faults, coal and gas outbursts at, 313.
—, — — — — —, reasons for, 319.
—, disintegration of coal at, 323.
—, Hanley, Deep pit, 313.
Feed-pumps, boilers, electric power-station, Grand Hornu, 650.
Feed-water, boilers, collieries, 339.
— —, —, Park Royal power-station, 641
FELLOWS, MORTON & CLAYTON, LIMITED, quoted, 347, 368.
Felspar coal-washers, Polmaise collieries, 243, 247.
FENWICK, FEATHERSTONE, election, N.E., 250.
Ferro-concrete and its applications, 10.
— — beams, construction, 10.
— — —, distribution of stresses in, 10.
— — coal-hoppers, Park Royal power-station, 641.
— — pillars, construction, 11, 12, 13.
Fichtelgebirge, Bavaria, stanniferous deposits, 679.
FICKLER, —, quoted, 250.
FIRCKS, BARON F., ore-deposits of province of Almeria, Spain, 701.
FIRCKS, CURT, auriferous deposits of Finnish Lapland, 693.
Fire-bricks, crushing strength of, 425.
Fire-clay, analyses, Siberia, Akmolinsk, 526.
Fire-damp, absence of, working of neighbouring seams and, 88.
— —, Courrières explosion, suggested cause of, 307.
— —, explosions and, 305.
— —, non-inflammable dust and explosions of, 326.

Fire-damp, outbursts, 307.
— —, —, Shelton colliery, 313.
— —, Pas-de-Calais district, regulations regarding, 307.
— — explosions, United Kingdom, 1906, summary, 725.
Fire-stoppings, Freehold colliery, 82, 87.
Fires, underground, Courrières collieries, cause, 303.
—, —, Freehold colliery, cause, 83.
—, —, quality of coal and, 83, 84.
—, —, Shropshire, 78.
—, —, —, sealing-off, 79, 82.
Fischer, H., mercury ore-deposits of Avala Hill, Servia, 697.
Fischer calorimeter, 285.
Fleetwood, Preesall, rock-salt deposits, mining, 291.
Fleetwood Salt Company, Limited, quoted, 292.
Flintshire coal-field, extensions, 40.
— coal-measures, thickness, 32.
Floors of seams, soft, difficulties due to, 103.
Florence Coal and Iron Company, Limited, apology to, 664.
Florence colliery, depth of workings, 38.
Flywheels, friction of air and, 55.
—, generators, electric power-station, Grand Hornu, 652.
Forbes, Urquhart A., *improvements required in inland navigation*, 377.
Forced draught for boilers, economies effected by, 338.
Fore-winning workings, Warwickshire thick coal, 507.
Forest of Wyre coal-field, extensions, 47.
Formulæ, rational, properties, 573.
Forrest, J. C., *hidden coal-fields of Midlands*, 266.
Forster, T. E., *liquid air and its use in rescue-apparatus*, 5.
—, *new apparatus for rescue-work in mines*, 182.
—, quoted, 577.
—, *sliding-trough conveyors*, 200.
Forth bridge, experiments on wind-gauges, 62.
Fossils, coal-measures, 268, 273.
—, — —, Midlands, 31, 33.
—, — —, Siberia, Akmolinsk, 526.
—, — —, —, Kuznetsk, 713.
—, — —, southern Manchuria, Fushun, 712.
—, — —, upper Silesia, 675.
—, Purbeck limestones, 471.
—, pyrites-deposits, Spain, Huelva, 706.
Foulis, John Thomas, election, N.E., 1.
Four Ashes bore-hole, coal-measures, 46.
France, coal output per man, 565.
—, packs, use of stone from quarries at surface, 516.
Franco-Servian mining glossary, 697.
Franklin, Benjamin, quoted, 457.
Franzes valley, Spain, Almeria, silver-bearing galena, 703.
Frech, Fritz, quoted, 675.
Freehold colliery, Shropshire, gob-fire, 78.
— —, —, section of double seam at, 78.
Freezing-process, sinking, Dawdon colliery, 197, 251.
— —, —, Monkwearmouth, 275.
— —, —, temperatures used, 251.
Freise, Fr., mineral-resources of Asia Minor, 708.
Friedrich Anna mine, brown-coal, upper Lausitz, 675.
Fryar, J. W., *application of duplicate fans to mines*, 436.
Fuel consumption at collieries, economies effected, 338 *et seq.*
Fungurume, Congo Free State, copper-ores, 722.
Furnace ventilation, gypsum-mines, Sussex, 467.
Fushantshun collieries, southern Manchuria, 712.
Fushun, southern Manchuria, coal-fields, 712.
Futers, T. C., *cast-iron tubbing*, 619.
—, *liquid air and its use in rescue-apparatus*, 9.
—, *sliding-trough conveyors*, 200.
—, *treatment of dust in mines*, 258.

G.

Gäbert, C., quoted, 681.
Galena, argentiferous, Switzerland, Cadlimo, 707.
—, Norway, Traag, 689.
—, Prussia, Hesse-Nassau, 680.
Galicia, Austria, Boryslaw, ozokerite-mine, 535.
Galizische Kreditbank, Austria, Galicia, Boryslaw, ozokerite-mine, 535.
Galliford, John, election, M.G., 277.
—, new reflector for safety-lamps in mines, 281.
Galloway, R. L., *application of duplicate fans to mines*, 444.
Galloway, R. L., quoted, 188.
Galloway, T. Lindsay, *effects of acceleration on winding-torques*, 52.
—, *tests of a mine-fan*, 60.
Galloway, W., *cast-iron tubbing*, 621.
—, quoted, 121, 123, 568, 571, 572, 621.
Garforth, W. E., new apparatus for rescue-work in mines. — Discussion, 180, 277.
—, quoted, 3, 6, 9, 205, 208, 212, 251.
Gas and coal outbursts, Shelton colliery, 313.
Gas-engines, air-lift pump driven by, 494, 495.

Gas-engines, electric power and, 415.
— —, fuel-consumption and, 340, 341.
— —, Sub-Wealden Gypsum Company, Limited, 464.
— —, surplus gases from coke-ovens and, 413.
Gas-power plant for electrical power, costs, 341.
Gas-producers, fuel-consumption and, 340.
Gases in mines, pressures recorded, 322.
Gastaldi, —, quoted, 684.
Gate-roads, machine-mining, 445.
Gay, H. S., single-room system of mining, adaptation of longwall method to work in thick seams, 558.
Gay Coal and Coke Company, West Virginia, quoted, 558.
Gellivaara, Sweden, iron-ores, 690.
Geloxite, permitted explosive, explosion caused by, 135.
Generators, electric power-plant, Boryslaw, ozokerite-mine, 536.
—, — — —, Clay Cross, 388.
—, — — —, Polmaise collieries, 240, 246.
—, — power-station, Grand Hornu, 648, 650.
—, — — —, Park Royal, 636.
Geological Society of South Africa, quoted, 557.
Geological Survey, quoted, 28, 266.
Geological Survey, Saxony, quoted, 682.
Geological Survey, South Africa, quoted, 550.
Geological Survey, Sweden, quoted, 693.
Geology, Austria, Galicia, Boryslaw, 536.
—, China, southern Manchuria, Fushun coal-fields, 712.
—, Congo Free State, Katanga, 721, 722.
—, Germany, Baden, Black Forest, nickeliferous magnetic pyrites deposits, 678.
—, —, Bavaria, Fichtelgebirge, stanniferous deposits, 679.
—, —, Hesse, Mettenheim, asphalt-deposits, 675.
—, —, Prussia, Hesse-Nassau, Holzappel metalliferous belt, 680.
—, —, Saxony. Halle-an-der-Saale, kaolin-deposits, 676.
—, —, —, tungsten-ores, 682
—, —, —, western Erzgebirge, pyrites-deposits, 681.
—, —, Silesia, upper Lausitz, brown-coal deposits, 673.
—, —, upper Silesia, coal-measures, 675.
—, Italy, Piedmontese Alps, graphite-deposits, 683.
—, —, Sardinia, copper-ores, 685.
—, —, —, tungsten-ores, 687.
—, —, Sicily, Messina, 687.
—, Midlands, coal-fields, 26.
—, Preesall, rock-salt deposits, 291.
Geology, Servia, Avala hill, mercury-ores, 697.
—, —, gold-fields, 696.
—, Shropshire, Freehold colliery, 78.
—, Siberia, eastern, Chukchen peninsula, 719, 720.
—, —, gold-bearing regions, 714, 716.
—, —, Kuznetsk, coal-fields, 713.
—, South Africa, 540.
—, — —, Orange River Colony, New Rand gold-field, 530.
—, Spain, Almeria, ore-deposits, 699, 701, 702, 703.
—, —, Huelva, pyrites-deposits, 705.
—, Sweden, northern, Gellivaara, 692.
—, —, —, iron-ore deposits, 691.
—, Switzerland, Cadlimo, galena deposits, 707.
—, water-bearing strata, list, 477.
Gerasimoff, A., and P. I. Preobrazhensky, gold-bearing regions of Siberia, 714.
German South-west Africa, geology, 547.
Germany, Baden, Black Forest, nickeliferous magnetic pyrites, 677.
—, Bavaria, Fichtelgebirge, stanniferous deposits, 679.
—, coal-output per man, 565.
—, coal-washing, developments in, 149.
—, gas-engines driven by waste-heat, 415, 421.
—, Hesse, Mettenheim, asphalt-deposit, 675.
—, Prussia, Hesse-Nassau, Holzappel metalliferous belt, 680.
—, Saxony, Halle-an-der-Saale, kaolin-deposits, 676.
—, —, tungsten-ores, 682.
—, —, western Erzgebirge, pyrites-deposits, 680.
—, Silesia, coal-measures, posidonia becheri in, 675.
—, —, upper Lausitz, brown-coal deposits, 673.
Gerrard, John, *liquid air and its use in rescue-apparatus*, 171.
—, *new apparatus for rescue-work in mines*, 280.
—, *rock-salt deposits at Preesall*, 299.
Gertrud mine, Saxony, tungsten-ores, 682.
Giabul, Asia Minor, salt deposits, 709.
Gibbon, W. Duff, election, S.S., 167.
Gibson, John, election, S.I., 236.
Gibson, Walcot, quoted, 28, 30, 31, 269.
Gierberg-Shamrock rescue-apparatus, Tankersley rescue-station, 215.
— — — —, — — —, cleaning of, 216.
Giese, —, quoted, 250.
Gill, J., quoted, 209.
Gill, T., *mining in Barnsley district*, 103.
Gillespie, Thomas R., election, S.I., 52.

Girders, steel and wood compared, 337.
Girdlestone, F. S., *improvements required in inland navigation*, 375.
Glasgow, barometer, height above sea-level, 725.
Glauber salts, use in rescue-apparatus, 278.
Gloucester and Birmingham Navigation Company, quoted, 375.
Glückauf mine, brown-coal, Silesia, 674.
Gneisenau colliery, pneumatogen trial at, 250.
Gob-fires, carbon dioxide for extinguishing, 517.
— —, causes, 521.
— —, Derbyshire main coal-seam, precautions against, 514.
— —, drowning-out of, 506.
— —, nature of floor and, 522.
— —, precautions against, 506.
— —, Shropshire mine, 78.
— —, timber in goaves and, 518.
— —, Warwickshire, thick coal-seam, 504.
— —, —, — — —, causes, 504.
Gold, minerals associated with, Siberia, placer-deposits, 718.
—, output, Servia, Kucajna mines, 697.
—, —, Siberia, Amgun, 717.
Gold-dredging, Servia, 696.
Gold-fields, New Rand, Orange River Colony, 530.
— —, Servia, 695.
Gold-ores, Asia Minor, 710.
— —, Congo Free State, Katanga, 723.
— —, Finnish Lapland, 693.
— —, Nizhne-Tagilsk, 695.
— —, Siberia, 714.
— —, —, eastern, Chukchen peninsula, 720.
Gold-placers, Californian, comparison with Katanga placers, 723.
— —, Congo Free State, cupriferous dedeposits and, 723.
— —, Finnish Lapland, 693.
— —, Korea, 713.
— —, river gradients and, 717.
— —, Siberia, 714.
— —, —, eastern, Thunilthan river, 720.
Gold quartz reefs, Korea, 713.
Gonzalo y Tarin, —, quoted, 704.
Görlitz-Ostritz, Siberia, brown-coal deposits, 674.
Gossans, copper-ore-deposits, Congo Free State, 722.
—, — — —, enrichment in, 706.
Goths or bumps, 313.
Goupillière, Haton de la, quoted, 622, 623.
Governors, engines, electric power-station, Grand Hornu, 651.
—, —, — — —, Park Royal, 636.
Grace, William Grace, election, N.E., 2.
Graham, D. A. L., quoted, 7.
Grahn, H., quoted, 223.
Grand Hornu, Belgium, electric transmission of power at works and collieries, 647.
— Junction canal, dredging, 351.
Grand Junction Canal Company, quoted, 350, 369.
Granite-masses, strike of strata and, South Africa, 541.
Graphite deposits, eastern Siberia, Telgakar, 720.
— —, Lapland, 693.
— —, Piedmontese Alps, 683.
Grashof, —, quoted, 596.
Gravesend and Rochester Railway and Canal Company, quoted, 353.
Gray, F. A., quoted, 233.
Gray, John, election, S.I., 236.
Grayston, F. A., *Hanley cage-guardian*, 168.
—, *hidden coal-fields of Midlands*, 50, 261.
—, quoted, 264.
Great Central Railway Company, quoted, 352.
Great Northern Railway Company, artesian tube-well, 486.
Great Western Railway Company, Park Royal power-station, 634.
—, quoted, 353.
Greaves, E., Elliott washer and Hardy dust-extractor and grinder, 138.—Discussion, 149.
Greaves, John Henry, election, M.I., 89.
Greenbow, W. Gordon, election, S.S., 25.
Greenwell, G. C., quoted, 123, 568, 569, 570, 571, 572, 589, 619, 627, 632.
Gregory, H. E., *use and care of oxygen-breathing apparatus*, 230.
Gregory, J., *Courrières explosion*, 309.
Griesbach, C. L., quoted, 545.
Griff colliery, depth of workings, 529.
— —, gob-fire caused by crushing of coal, 504.
— —, — — — — oxidation of pyrites, 505.
— —, haulage, 511.
Grinder for coal, 148.
Grinding, rock-salt, Preesall salt-mine, 297.
— machinery, cement manufacture, Knight, Bevan & Sturge works, 644.
Griqualand West, South Africa, geology, 547.
Groddeck, Von, quoted, 698.
Gueritte, T. J., ferro-concrete and its applications, 10.
Guibal, T., quoted, 438.
Guides for cages, safety, 169.
— — —, steel-rail, 110.
— — —, — —, costs, 111.
— — —, wire-rope, 104, 111.
— — —, — —, costs, 112, 118.

Guides for cages, wire-rope, effect of safety device on, 166.
— — —, — —, rubber-ropes for use with, 106, 107.
— — —, wooden, 109.
— — —, —, costs, 110, 118.
— — —, —, disadvantages, 113 *et seq.*
— — — for winding from deep shafts: 1,500 feet and deeper, 104, 108.—Discussion, 113.
Gunpowder, black, rock-salt mining, 294.
—, permitted explosives and, 188.
GURNEY, GOLDSWORTHY, quoted, 278.
Gute Hoffnung mine, Hesse-Nassau, white dykes, 680.

H.

HABERSHON, M. H., *guides for cages*, 114.
—, use and care of oxygen-breathing apparatus, 212.—Discussion, 222.
Hackney baths, artesian tube-well, 487.
HAGEMANN, F., *use and care of oxygen-breathing apparatus*, 227.
HALBAUM, H. W. G., *application of duplicate fans to mines*, 440.
—, cast-iron tubbing: what is its rational formula, 567.—Discussion, 617, 664.
HALDANE, J. S., quoted, 3, 8, 85, 214, 226.
HALL, A. L., quoted, 546, 550.
HALL, HENRY, *thick coal of Warwickshire*, 516.
HALL, ROBERT WILLIAM, election, N.E., 249.
HALL, T. Y., quoted, 3.
Ham-Kyeng, Korea, copper-ores, 713.
HAMILTON, ALEXANDER, election, S.I., 236.
HAMILTON, JAMES, election, vice-president, S.I., 153.
Hamstead colliery, south Staffordshire, coal-field extensions, 44.
— —, — —, fires at, 513.
— —, — —, precautions against fires, 518.
HANLEY, ALBERT, Hanley cage-guardian, 164.—Discussion, 168.
Hanley, Deep pit, coal and gas outbursts, 313.
HARDY dust extractor, 143.
HARE, S., *explosion at Wingate Grange colliery*, 191.
HARLE, RICHARD, treatment of dust in mines, aboveground and belowground, 254.—Discussion, 257.
HARLESSEN, — VON, quoted, 250.
HARPEN COLLIERY, LIMITED, Dortmund, quoted, 658.
HARRISON, GEORGE B., *cage-lowering tables*, 178.
Hartley colliery, effect of mine-waters on iron, 577.
HASSAM, A., 87.
—, *outbursts*
HASTINGS AN AND PHIL 452.
Haswell coll cised, 196.
HATCH, F. H
Hatfield wa 490.
Haulage, ele mines, Sus
—, — power
—, main-and 511.
—, main-rop 247.
—, secondary power, 337
—, —, Griff
—, —, headi and, 73.
—, Siberia,
—, Warwick 510.
—, water-sp
Haulage-engi seams, 96.
Hauling arra
Haunchwood 264.
Hawkesbury at, 263.
Headgears, and, 106.
—, Polmaise
Heading by
— — — —,
— — — —,
Heading-ma economies
— —, rate of compared,
— —, rock-s
— —, types
Headings, pu

HEDLEY, A. M., *explosion at Wingate Grange colliery*, 195.
Heidelberg, South Africa, granite-masses, 542.
HENDERSON, JAMES, election, S.I., 236.
HENDERSON, PETER, election, S.I., 236.
HENDY, J. C. B., *application of duplicate fans to mines*, 434.
HENNEBIQUE system, ferro-concrete, bridges constructed on, 19.
— —, — —, reservoirs constructed on, 15.
HENSHAW, A. M., *gob-fire in Shropshire mine*, 85.
—, *outbursts of coal and gas*, 322.
—, quoted, 3.
HENSHAW, A. M., and W. N. ATKINSON, Courrières explosion.—Discussion, 124, 303, 326.
Heraklea coal-mine, Asia Minor, 711.
HERING superheater, boilers, electric power-station, Grand Hornu, 649.
Hermsdorf-Schönbrunn, Silesia, brown-coal deposits, 674.
Herrerias, Spain, Almeria, iron- and silver-ores, 703.
Hesse, Mettenheim, asphalt-deposits, 675.
Hesse-Nassau, Prussia, Holzappel metalliferous belt, 680.
Hetton colliery, explosion due to underground boilers, 668.
HEWITT, H. R., *sinking and tubbing at Methley Junction colliery*, 121.
—, *thick coal of Warwickshire*, 513.
Hibernia collieries, rescue-work, 213, 228.
HIGGINBOTTOM, H. SHARROCK, election, S.S., 261.
HILGENSTOCK, —, quoted, 422.
HILL, G. BAILLIE, election, S.S., 261.
Himley collieries, method of working, 515.
HIND, WHEELTON, quoted, 28.
Hoang-Hai, Korea, iron-ores, 713.
HODGES, I., account of sinking and tubbing at Methley Junction colliery, etc.—Discussion, 120.
HODGES, I., *Courrières explosion*, 130.
—, *gypsum in Sussex*, 468.
—, *notes on bye-product coke-ovens*, 421.
—, quoted, 567, 575, 576, 578, 579, 580, 604, 607, 620.
HODGSON, L. H., *pneumatogen*, 251.
Holing, machine-cutting, depth of, 71.
—, — —, hard ground, 159.
—, — —, height of, 445.
HOLLAND, L., *thick coal of Warwickshire*, 519.
HOLLINGWORTH, G. H., quoted, 568, 571, 572, 632.
Holzappel, Hesse-Nassau, metalliferous belt, 680.
HOOD, THOMAS WIGHTON, election, M.I., 89.
Horbach mine, Baden, minerals found in, 677.
Horbachite, nickeliferous magnetic pyrites and, 677.
HORWOOD-BARRETT, HAROLD, election, N.E., 249.
HOWAT, JOHN T., election, councillor, S.I., 153.
HOWAT, WILLIAM, election, councillor, S.I., 153.
HOWELL, H., quoted, 264.
HOWIE, ANDREW SNEDDON, election, S.I., 153.
HOWSON, CHARLES, election, N.E., 249.
Hpyeng-Yang coal-fields, Korea, 713.
Huelva, Spain, pyrites-deposits, 704.
HUESSENER coke-ovens, cost of repairs, 419, 420, 428.
HUGHES, JOHN, quoted, 274.
HULL, EDWARD, *gypsum in Sussex*, 470.
—, quoted, 50.
Humic acid, kaolin deposits and, 677.
HUNTER, HERBERT STANLEY, election, N.E., 2.
HUNTER, JONATHAN, election, S.S., 167.
HUNTER, W. H., quoted, 380.
Hydraulic posts for support of roof, 559.

I.

Igneous rocks, Shropshire, disturbances in strata adjacent to, 78.
INGERSOLL-SERGEANT coal-cutting machines, Preesall salt-mine, 295.
— — heading-machines, electrically-driven air-compressors combined with, 501.
Inland navigation, difficulties, 358.
— —, improvements required in, 347.
INSKIPP, DUDLEY JAMES, election, N.E., 249.
INSTITUTION OF CIVIL ENGINEERS, quoted, 366, 373.
INSTITUTION OF MINING ENGINEERS, founding of, 203, 330.
INTERNAL TRANSPORT COMMITTEE OF SOCIETY OF CHEMICAL INDUSTRY, quoted, 372.
Iron, effect of concrete on, 22.
Iron-manganese ores, Spain, Almeria, 703.
Iron-ores, Asia Minor, 710.
— —, Italy, Sicily, 688.
— —, Korea, 713.
— —, Lancashire, Fleetwood, search for, 291.
— —, Russia, Nizhne-Tagilsk, 695.
— —, Siberia, eastern, Chukchen peninsula, 720.
— —, —, Kuznetsk, 714.

Iron-ores, Spain, Almeria, minerals associated with, 702.
— —, Sweden, northern, Gellivaara and Kiirunavaara, 690.
— —, —, —, output, 690, 692.
Ironstone, Cleveland, discovery of, 665.
—, —, phosphorus in, difficulties due to, 666.
—, Westbury, 470.
Isle of Man, rock-salt deposits, 299.
Isler & Company, C., London, quoted, 473.
Isola Grande graphite-mine, Ligurian Alps, 684.
Issala, Sicily, lead-and-zinc ores, 688.
Italy, Piedmontese Alps, graphite-deposits, 685.
—, Sardinia, Castello di Bonvei, azurite-deposits, 685.
—, Sicily, mineral deposits, 687.
Ivanoff, M. M., E. Ahnert, A. Khlaponin, P. Rippas and P. Yavorovsky, gold-bearing regions of Siberia, 714.

J.

Jackson, Douglas, election, councillor, S.I., 153.
Jackson, W. B. M., bye-product coking-plant at Clay Cross, 386.
Jacobs, Lionel Asher, election, N.E., 179.
Jacobson, Richard, *use and care of oxygen-breathing apparatus*, 231.
Jaggar, Joseph, election, M.I., 89.
Jalinda, Siberia, gold-deposits, 716.
Jamieson, Andrew, quoted, 596.
Jamieson, Thomas J., election, councillor, S.I., 153.
Japan, coal-fields, Manchurian coal-fields and, 712.
Jaroso valley, Spain, Almeria, silver-bearing galena, 703.
Jeppe's hill, South Africa, origin of, 557.
Jerina adit, Servia, mercury-mine, 698.
Jig coal-washing machine, Barraclough, coking-plant, Clay Cross, 390.
Joel, J. E., quoted, 189.
Johannesburg granite-mass, folding of strata near, 551.
Johannesburg granite-mass, strike of strata and, 542.
Johnson, Henry, *hidden coal-fields of Midlands*, 50.
—, quoted, 28, 274.
Johnson, J. P., quoted, 554.
Johnston, James F. W., quoted, 457.
Johnstone, Hugh, *Courrières explosion*, 304.
—, election, N.S., 76.
—, *thick coal of Warwickshire*, 522.
Jones, Daniel, *hidden coal-fields of Midlands*, 264.
—, quoted, 33.
Jones, Evans, election, N.E., 179.
Jones, St. V. Champion, gob-fire in Staffordshire mine, 78.—Discussion, 84.
Jorissen, E., quoted, 541, 542, 543.
Joseph Hermann mine, brown-coal, upper Lausitz, 674.
Jovanovitch, Douchan, auriferous deposits of Servia, 695.
Jukes, J. B., quoted, 28, 264.
Jura, Alps, origin of, 553.

K.

Kalabak, Asia Minor, copper-ores, 711.
Kambove, Congo Free State, copper-ores, 722.
—, — — —, gold-placer, 723.
Kaolin, origin of, 676.
—, — —, humic acid and, 677.
Kaolin-deposits, Saxony, Halle-an-der-Saale, 676.
Kap-San, Korea, copper-ores, 713.
Karlik tacheograph, electric winding-engines, Grand Hornu colliery, 661.
Karroo, South Africa, folding of strata, 552.
Karroopoort, South Africa, geology, 547.
Kasten or washing tank, 700.
Katanga, Congo Free State, copper, tin and gold deposits, 721.
Keeling, G. W., *improvements required in inland navigation*, 382.
Keillar, T. W., election, M.I., 89.
Kemp, W. J., and G. Alfred Lewis, gypsum in Sussex, 449.—Discussion, 468.
Kendall, Percy Fry, quoted, 28, 38, 39.
Kennedy, A. J., *application of duplicate fans to mines*, 438.
—, most suitable form of guides for cages for winding from deep shafts: 1,500 feet and deeper, 108.—Discussion, 113.
Kent, Northfleet, Knight, Bevan & Sturge cement-works, 642.
— coal-field, discovery of, 470.
Kerbi river, Siberia, gold-placers, 716.
Kershaw, J. B. C., quoted, 288.
Kew, barometer, height above sea-level, 725.
Khlaponin, A., gold-bearing regions of Siberia, 714.
Khlaponin, A., E. Ahnert, M. M. Ivanoff, P. Rippas and P. Yavorovsky, gold-bearing regions of Siberia, 714.
Khunho, southern Manchuria, coal-field, 712.
Kiirunavaara, Sweden, iron-ores, 690.

Killingworth colliery, Fleuss rescue-appliance at, 182.
KIND-CHAUDRON tubbing, formula for thickness, 625, 632.
KING, WILLIAM, election, S.I., 236.
KING'S LYNN CONSERVATORS, quoted, 355.
Kinzigites, graphitiferous, Italy, Calabria, 685.
KIRKBY, R., *thick coal of Warwickshire*, 520.
KIRKLEY, JAMES, election, N.E., 250.
KIRKUP, ERNEST HODGSON, election, N.E., 180.
KIRKUP, J. P., *explosion at Wingate Grange colliery*, 188.
KIRKUP, PHILIP, *electrically-driven air-compressors*, 501.
—, *explosion at Wingate Grange colliery*, 186.
—, *gypsum in Sussex*, 470.
Kiruna, Sweden, iron-ores, 690.
KLEIN coal-measuring boxes, Park Royal power-station, 642.
— cooling-towers, condensing-plant, Park Royal power-station, 639.
Kleinite, mercury oxychloride, Servia, 698.
KLOCKMANN, —, quoted, 704.
Knight, Bevan & Sturge works of Associated Portland Cement Manufacturers (1900), Limited, Northfleet, Kent, 642.
KOCHS, A. VICTOR, notes on bye-product coke-ovens, with special reference to Koppers oven, 398.—Discussion, 416.
Kolchan river, Siberia, gold-placers, 715.
Kolwezi, Congo Free State, copper-ores, 722.
Komatipoort, South Africa, absence of great fault, 546.
KOPPERS, HEINRICH, quoted, 398.
KOPPERS bye-product coke-ovens, 398.
— — — — —, distinguishing features of, 404.
— — — — —, output from, 415.
— — — — —, regulation of, 404.
Korea, coal-fields, 713.
—, mineral deposits, 712.
KORSUCHIN, J., mineral resources of Chukchen peninsula, eastern Siberia, 719.
KRASNOPOISKY, A., manganiferous and other ore-deposits of Nizhne-Tagilsk, Russia, 695.
KRUGER, PRESIDENT, quoted, 531.
Kucajna, Servia, gold-mines, 697.
—, —, sulphide ores, 696.
Kuznetsk, Siberia, coal-fields, 713.
Kyeng-Syang-To, Korea, rock-salt deposits, 713.
Kyeng-Tjyon, Korea, rock-salt deposits, 713.
KYLE, WILLIAM, election, S.I., 52.
KYNASTON, H., quoted, 546.

L.

La Caridad, Spain, ore-deposits, 705.
Labour, coke-ovens, Clay Cross, 395.
—, collieries, improvements in conditions of living, 345.
—, South Africa, 533.
LAMÉ, —, quoted, 596, 621, 622, 625, 629.
Lancashire boilers, adoption for colliery purposes, 338.
— —, coking-plant, Clay Cross, 388.
— —, fuel consumption, 167.
— —, Polmaise collieries, 239, 245.
— coal-field, extensions, 40.
— coal-measures, thickness, 32.
Lancaster canal, 352.
Lapland, Finnish, gold-bearing deposits, 693.
—, —, graphite-deposits, 693.
LAPPARENT, A. DE, quoted, 723.
LAPWORTH, CHARLES, hidden coal-fields of the Midlands, 26.—Discussion, 50, 261.
Lauban, Silesia, brown-coal deposits, 674.
LAUNAY, L. DE, quoted, 691.
Lausitz, upper, Silesia, brown-coal deposits, 673.
LAVERICK, J. H. W., *thick coal of Warwickshire*, 514.
LAWRENCE, HENRY, *new apparatus for rescue-work in mines*, 182.
—, *sliding-trough conveyors*, 200.
LAWTON, G. E., *gob-fire in Shropshire mine*, 85.
LE CHATELIER, H., quoted, 310.
LEACH, C. C., *application of duplicate fans to mines*, 433, 444.
—, *explosion at Wingate Grange colliery*, 188.
—, *liquid air and its use in rescue-apparatus*, 5.
—, *thick coal of Warwickshire*, 517.
—, *treatment of dust in mines*, 258.
Lead, output, Servia, Kucajna mines, 697.
Lead-and-zinc veins, Sicily, 688.
Lead-ores, Asia Minor, 710.
— —, Norway, Traag, 689.
— —, Spain, Almeria, 699, 701, 703.
— —, —, —, output, 701.
Leases, mining, subsidence clauses in 336.
Lebotwood coal-field, strata, 33.
LECKIE, JAMES, election, S.I., 236.
Leeds and Liverpool canal, dredging, 351.
LEGGATT, ROBERT, election, S.I., 236.
Legislation, affecting mining, 1906, 334.
Leicestershire coal-field, extensions, 42, 43, 44.
— — —, strata, 33.
Lena river, Siberia, gold-placers, 715.
Lens collieries, sliding-trough conveyors, 198.

Leopoldine Louise mine, Prussia, Dörnberg, main lode at, 680.
Lethuillier-Pinel safety-appliances, boilers, electric power-station, Grand Hornu, 649.
Lewis, George, quoted, 466.
Lewis, G. Alfred, *Courrières explosion*, 125.
—, *water-supplies by tube-wells*, 497.
Lewis, G. Alfred, and W. J. Kemp, gypsum in Sussex, 449.—Discussion, 468.
Lewis-Thompson calorimeter, 285.
Leydsdorp, South Africa, folding of strata, 544.
Lichtenau-Geibsdorf, Silesia, brown-coal deposits, 674.
Liége, Belgium, ferro-concrete bridge, 18.
Liesenfeld, Prussia, metalliferous belt, 680.
Lighting, Boryslaw ozokerite-mine, 538.
—, gypsum-mines, Sussex, 468.
Lignite, Asia Minor, Rasheya, 710.
—, Silesia, upper Lausitz, 673.
Likasi, Congo Free State, copper-ores, 722.
Lilleshall Company, Limited, quoted, 78.
Limestone boulders, Preesall, 293.
Lindsay, George A., election, S.I., 236.
Lineham, W., quoted, 596.
Liquid air, cost of manufacture, 2.
— —, plant for manufacture, cost, 9, 170.
— —, respiration and, 5.
— — and its use in rescue-apparatus.—Discussion, 2, 170.
Liquid-resistance starters, electric winding-engines, Grand Hornu colliery, 658.
Little Khingan, Siberia, gold-placers, 715.
Littlewood, George Patrick, election, M.C., 120.
Livingstone ravine, Congo Free State, gold-placers, 723.
Llewellyn, Owen J., *improvements required in inland navigation*, 370.
Lloyd, W. D., *use and care of oxygen-breathing apparatus*, 225.
Locked-coil ropes for guides for cages, 113.
— — winding-ropes, vibration of guide-ropes and, 117.
— — — —, Wombwell Main colliery, 116.
Lockett, W
307.
—, *outburst*
Lomero cop
London, un
London an
Company
London Fi
Longden, C
Longridge
Longridge
Longwall
type, hea
— — — —
— working
— —, coal
— —, fillin
and, 72.
— —, gob-
— —, gyps
— —, — —
— —, hydr
at face, 5
— —, singl
to thick
— —, — —
— —, thick
— —, — —
Lossanitsc
Lotti, B., n
eastern S
Louis, Her
—, *liquid a*
ratus, 4.
—, quoted,
Louisa min
Schönbru
Lovisato,
Cagliari
Löwenberg
674.
Lowenstei
election,
Lubricatio
Lugeon, M
Luka, Serv
Luossajärv
Luossavaar
691, 692.
Lupton, A
—, *thick co*
Luushia, C
722.
Lydenburg
strata, 5
Lyell, Sir
269.

M.

Macclesfield canal, 352.
McGuffie, H. A., election, S.I., 236.
Machine-mining, practical problems of, 445.
— —, Preesall salt-mine, 294.
Mackay, A
Mackey,
oxygen-b
Mackintos
S.I., 236

McLuckie, John, *heading by longwall machines*, 160.
M'Meekin, Thomas, election, S.I., 153.
M'Neill, Kirkwood Hewat, election, S.I., 52.
M'Phail, James, election, councillor, S.I., 153.
M'Trusty, John W., election, S.I., 153.
Madeley colliery, coal-field extensions, 47.
Magaliesberg range, South Africa, origin of poorten in, 550.
Magnesia, fire-damp and, explosions, 326.
Magnesium chloride, use in freezing-process, Monkwearmouth, 276.
Magnetic-locks, safety-lamps, Polmaise collieries, 241.
Magnetic-pyrites, analyses, Sicily, 688.
— —, Germany, Saxony, western Erzgebirge, 681.
— —, nickeliferous, Baden, Black Forest, 677.
Magnetite, graphite associated with, Lapland, 693.
—, Russia, Nizhne-Tagilsk, 695.
—, Sicily, 688.
—, Sweden, Kiirunavaara, 691.
Magniette composition for steam pipes, 650.
Mahler calorimeter, 286.
Maidan-Pek, Servia, sulphide ores, 696.
Maier, Ernst, gold-bearing regions of Siberia, 716.
Main-and-tail rope haulage, water-spraying of tubs, 256.
Main-rope haulage, Polmaise collieries, 241, 247.
Majdanpek, Servia, gold associated with chalcopyrite, 697.
Makry, Asia Minor, chrome-iron-ore, 710.
Malachite, Congo Free State, 721.
—, Italy, Sardinia, 685.
—, Spain, Almeria, 699.
Malone, Thomas, election, S.I., 236.
Malplat, M., sliding-trough conveyors, 198.—Discussion, 200.
Maltosrova, Lapland, graphite-deposit, 693.
Malvern, shot-drilling boring-plant at, 482.
Manchester ship canal, dredging, 351.
— — —, progress of, 374.
Manchuria, southern, Fushun, coal-fields, 712.
Manganese-iron-ores, Spain, Almeria, 703.
Manganese-ores, Asia Minor, 710.
— —, Russia, Nizhne-Tagilsk, 695.
— —, Spain, Huelva, 707.
Mann, Otto, pyrites-deposits of western Erzgebirge, Saxony, 680.
Mannesmann rolled steel tubes, rising-main for pumps, Grand Hornu colliery, 662.
Manor pit, coal-measures, 45.
Mara, Sardinia, copper-ores, 685.
Mariani, E., argentiferous galena of Cadlimo, Switzerland, 707.
Marklissa, Silesia, brown-coal deposits, 674.
Marshall, Albert, election, N.S., 303.
Marshall, J. L., *mining in Barnsley district*, 101.
Martin, Henry Stuart, election, N.E., 179.
Martin, J. S., *gypsum in Sussex*, 469.
Mavor, Sam, heading by longwall machines, 65.—Discussion, 157.
—, practical problems of machine-mining.—Discussion, 445.
—, *tests of a mine-fan*, 62.
Maxwell, J. Clerk, quoted, 575.
Meachem, F. G., quoted, 324.
Mechanical engineering of collieries, improvements, 336.
Meerschaum deposits, Asia Minor, 709.
— —, — —, output, 709.
Mellin's food factory, water-supply for, 479.
Mellor, E. T., quoted, 553, 554.
Menteshderé lead-mine, Asia Minor, 710.
Menzies, John, election, councillor, S.I., 153.
Mercury, Servia, gold-bearing, 696.
—, —, output, 698.
Mercury-ores, Asia Minor, 710.
— —, genesis, Servian and Californian deposits compared, 698.
— —, Servia, Avala hill, 697.
Mercury-vapour electric lamps, Preesall salt-mine, 297.
Merivale, J. H., *explosion at Wingate Grange colliery*, 196.
—, *liquid air and its use in rescue apparatus*, 9.
—, quoted, 568.
—, *sinking by freezing-process*, 253.
—, *sliding-trough conveyors*, 200.
—, *treatment of dust in mines*, 257.
Merryweather fire-extinguishers, use in mines, 518.
Messina, Sicily, geology, 687.
Metallurgy, notes of colonial and foreign papers on, 673.
Methley Junction colliery, shaft-tubbing, composition for preserving, 580.
— — —, — —, corrosion, 576, 607.
— — —, sinking and tubbing, 120.
Metropolitan Water Board, quoted, 378.
Mettenheim, Hesse, asphalt-deposit, 675.
Meyer, G. A., quoted, 2, 9, 212, 213, 216, 227, 280, 281.
Meymacite, decomposed scheelite, 687.
Michael, R., posidonia becheri in upper Silesian coal-measures, 675.
Midland Institute of Mining, Civil and Mechanical Engineers, report on rescue-work, Altofts collieries, 209.

Midlands, hidden coal-fields, 26, 261.
—, — — —, depths of seams, 49.
—, — — —, estimated areas, 49.
Mikhailo-Ivanovsky gold-placers, Siberia, 715.
Millar, Robert, quoted, 99.
Millosevich, F., azurite-deposit of Castello di Bonvei, Sardinia, 685.
Mineral deposits, Asia Minor, 709.
— —, Austria, Galicia, Boryslaw, ozokerite, 535.
— —, Congo Free State, Katanga, copper, tin and gold, 721.
— —, Finnish Lapland, gold-bearing, 693.
— —, — —, — —, origin of placers, 695.
— —, — —, graphite, 693.
— —, — —, —, origin, 693.
— —, Germany, Baden, Black Forest, nickeliferous magnetic pyrites, 677.
— —, —, —, — —, — — —, genesis, 679.
— —, —, Bavaria, Fichtelgebirge, tinstone, 679.
— —, —, —, —, —, origin, 679.
— —, —, Hesse, asphalt, 675.
— —, —, Prussia, Hesse-Nassau, lead, silver, zinc and copper-ores, 680.
— —, —, Saxony, kaolin, 676.
— —, —, —, —, origin, 676, 677.
— —, —, —, tungsten-ores, 682.
— —, —, —, western Erzgebirge, pyrites-deposits, 680.
— —, —, —, — —, — —, genesis, 681.
— —, Italy, Piedmontese Alps, graphite, 683.
— —, — —, —, —, origin, 683.
— —, —, Sardinia, copper-ores, 685.
— —, —, —, — —, genesis, 686.
— —, —, —, tungsten-ores, 686.
— —, —, Sicily, north-eastern, 687.
— —, —, —, — —, genesis, 689.
— —, Korea, 712.
— —, Lancashire, Preesall, rock-salt, 291.
— —, Norway, Traag, blende and galena, 689.
— —, —, —, — — —, genesis, 690.
— —, Russia, Nizhne-Tagilsk, manganese and other ore-deposits, 695.
— —, Servia, gold, 695.
— —, —, —, origin, 696.
— —, —, mercury-ores, 697.
— —, —, — —, genesis, 698.
— —, Siberia, gold, 714.
— —, —, eastern, 719.
— —, South Africa, New Rand, gold, 530.
— —, south of England, recent discoveries, 470.
— —, Spain, Almeria, 699.
— —, —, —, genesis, 699, 702, 703.
— —, —, Huelva, pyrites, 704.
— —, —, —, —, genesis, 704 *et seq.*
— —, Sussex, gypsum, 449.
Mineral deposits, Sweden, northern, iron-ores, 690.
— —, —, —, — —, genesis, 691, 692.
— —, Switzerland, Cadlimo, argentiferous galena, 707.
Mines, working of, notes of colonial and foreign papers on, 673.
Mining, various branches, death rate per 1,000, 334.
— engineers, training of, 332.
Mitchell, T. W. H., *mining in Barnsley district*, 102.
Mlava, Servia, gold-fields, 695, 697.
Moisture in coal, precautions in estimating, 284.
Molengraaff, G. A. F., quoted, 540, 541, 542, 545, 546, 549, 553.
—, *structural geology of South Africa*, 557.
Molesworth, Sir Guilford, quoted, 577.
Molybdenite, Saxony, 682.
Monazite, gold-placers, Finnish Lapland, 694.
Mond gas-power plant for producing electricity, costs, 341.
Monkswell, Lord, quoted, 136.
Monkwearmouth, C pit, 275.
Monmouthshire canal, Newport, severing of, 353.
Monmouthshire Railway and Canal Company, quoted, 353.
Monte Rubio copper-mine, Spain, Huelva, 707.
— Tossazza, Sicily, lead-and-zinc ores, 688.
Moore, R. T., *effects of acceleration on winding-torques*, 54.
—, election, president, S.I., 153.
—, *tests of a mine-fan*, 157.
Morgan-Gardner electric coal-cutting machine, Gay Coal and Coke Company, 559.
Morrow, J., *cast-iron tubbing*, 628.
Morton, J. Chalmers, quoted, 457.
Motors, electric, Belgium, Grand Hornu colliery, 647, 648, 650, 661, 662.
—, —, coal-cutting machines, 446, 447.
—, —, Park Royal power-station, condensing-plant, 639.
—, —, — — — —, exciter sets, 636.
—, —, Polmaise collieries, haulage, 241, 247.
—, —, — —, pumps, 240, 242, 247.
—, —, — —, screening and washing plant, 243.
—, —, — —, Sirocco fan, 239.
Mottram, Thomas H., election, vice-president, S.I., 153.
—, *tests of a mine-fan*, 61.
Mountain, W. C., commercial possibilities of electric winding for main shafts and auxiliary work.—Discussion, 150.
Mountain or fold-producing pressures, geology, South Africa, 540.
Muck, Joseph, quoted, 536.

MURCHISON, RODERICK, quoted, 50.
MURDOCH, ADAM, election, S.I., 52.
MURGUE, D., *application of duplicate fans to mines*, 434.
MURTON, EDWARD, quoted, 186.
Murton colliery, shaft-tubbing, cement-concrete lining, 579.
— —, watering at, 191.
Muskau, Silesia, brown-coal deposits, 674.

N.

Nagorny placer-mine, Siberia, 715.
Namrun, Asia Minor, coal-field, 711.
NASH, H. B., *mining in Barnsley district*, 102.
—, quoted, 209.
NASMITH, G. G., quoted, 7.
Natal, strike of strata, 545.
NAUMANN, —, quoted, 710.
Navigation, inland, improvements required, 347.
Neresnica, Servia, gold-dredging, 697.
NESS, GEORGE, effects of acceleration on winding-torques, and test of Tarbrax electrical winding-plant.—Discussion, 52.
Netherfield bore-hole, Sussex, 449, 470.
— — —, —, section of strata, 452.
Neumühl colliery, ventilation, water-gauge, 344.
NEVIN, JOHN, *improvements required in inland navigation*, 383.
New Moss colliery, cage-lowering tables, 174.
— Rand gold-field, Orange River Colony, 530.—Discussion, 531.
Newdigate colliery, coal-seams at, 503.
— —, gob-fires, precautions necessary, 505.
— —, haulage, 512.
— —, Warwickshire coal-field extensions, 44.
NEWTON, CHAMBERS & COMPANY, LIMITED, quoted, 209.
NICHOLLS, —, quoted, 380.
NICHOLSON, THOMAS PERCY, election, M.C., 120.
Nickeliferous magnetic pyrites, Baden, Black Forest, 677.
Nilan river, Siberia, gold-placers, 716.
Nizhne-Tagilsk, Russia, manganiferous and other ore-deposits, 695.
NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS, founding of, 202.
, quoted, 310.
North Staffordshire canal, dredging, 351.
NORTH STAFFORDSHIRE RAILWAY COMPANY, quoted, 352, 371.
North Wales, slate-mining, 516.
Northfleet, Kent, Knight, Bevan & Sturge cement works, 642.
Norway, Traag, blende- and galena-deposits, 689.
Nottingham, water-supplies from wells, 498.
Nottinghamshire, east, Thurgarton boring, section of strata, 31.
— coal-field, extensions, 38, 39.
— — —, strata, 33.
NOVARESE, VITTORIO, graphite-deposits in Piedmontese Alps, 683.

O.

Oakgates colliery, coal-field extensions, 47.
OATES, CHARLES, election, M.C., 120.
Oberwies, Prussia, metalliferous belt, 680.
O'DONAHUE, T. A., *cast-iron tubbing*, 617.
—, quoted, 599.
Officers, election, S.I., 153.
—, 1906-1907, x.
Oil-separating and filtering, Park Royal power-station, 639.
Oil-shale partings in coal-seams, gob-fires and, 506.
Oil-switches, automatic, electric power-station, Grand Hornu, 654.
OLDFIELD, WILLIAM, election, M.G., 282.
Olivadi graphite-mine, Calabria, Italy, 685.
OLIVER, THOMAS, *liquid air and its use in rescue-apparatus*, 5.
Olsnitz, Saxony, tungsten-ores, 682.
Omni-lateral pressure, influence on strata, South Africa, 543.
ONIONS, J. T., *boilers for colliery purposes*, 167.
Orange River Colony, folding of strata, 544.
— — —, New Rand gold-field, 530.
ORMROD, WILSON, election, N.E., 1.
ORNSBY, R. E., quoted, 577.
Orogenic forces, formation of pans and, 555.
— —, influence on strata, South Africa, 542.
O'SHEA, L. T., *notes on bye-product coke-ovens*, 416.
OTTO COMPANY, quoted, 422.
OTTO-HOFFMANN bye-product coke-oven, features of, 402.
OUSE HALING-WAYS COMMISSIONERS, quoted, 355.
Ouseburn culvert, Newcastle-upon-Tyne, ferro-concrete in construction of, 15.

Outbursts of coal and gas in Cockshead seam, Shelton colliery, 313.—Discussion, 320.
Overwinding, device for preventing, electric winding-engines, Grand Hornu colliery, 660.
Oxford, university of, quoted, 331.
Oxidation of coal, gob-fires due to, 505.
Oxygen, compressed, nitrogen in, 223, 226.
—, rescue-apparatus, pressure required, 219.
—, respiratory phenomena, 214.
Oxygen, use in determining calorific values, 285.
Oxygen-breathing apparatus, greasy substances prohibited in, 219.
— — —, rust in, dangers, 219, 226.
— — —, use and care of, 212.—Discussion, 222.
Ozokerite, uses of, 535.
Ozokerite-mine, Austria, Galicia, Borysław, 535.
— —, —, —, —, dressing operations, 538.
— —, —, —, —, gases, 536.
— —, —, —, —, output, 539.

P.

Packington bore-hole, coal-measures at, 262, 264, 271, 272.
Packs, thick coal, Warwickshire, 513.
—, use of stone from quarries at surface, 514, 515, 516.
Palapóviö, Lapland, graphite, 693.
Palibin, J., coal-bearing beds of southern Manchuria, 712.
Palladium associated with gold, Congo Free State, 724.
Pandermite, borate of lime, Asia Minor, 709.
Panel workings, fiery seams, 519.
Pans, South Africa, origin of, 549, 553, 555.
Papers, subjects for, xviii.
—, working of mines, metallurgy, etc., notes of colonial and foreign papers on, 673.
Park, James, election, S.I., 236.
Park Royal power-station, Great Western Railway Company, 634.
Parr calorimeter, 285.
Partidarios or lessees, 700.
Past-presidents, list, x.
Patchell, W. H., *application of duplicate fans to mines*, 437.
Paterson water-softening plant, Park Royal power-station, 639.
Peak Forest canal, 352.
Peasegood, W. G., *Courrières explosion*, 303.
Peat, William, quoted, 186.
Peat, Nizhne-Tagilsk, 695.
Pebworth, H. T., election, N.S., 312.
Pek, Servia, gold-fields, 695.
Pelouze-Audouin tar-separator, coking-plant, Clay Cross, 396.
Pendleton colliery, depth of workings, 38.
Percussion boring, 480.
Perkin, Herbert, *guides for cages*, 113.
Perkins engines and boilers, Sub-Wealden Gypsum Company, Limited, 461.
Peters' cement-works, water-supply, 484.
Petrol-motors for canal-boats, dangers, 362.
Petroleum, associated with gypsum, 452.
—, Austria, Galicia, output, 535.
Peyton, J. E. H., quoted, 452.
Philippson, A., quoted, 709.
Phillips, W. G., *Courrières explosion*, 135.
—, *Elliott washer and Hardy dust-extractor*, 149.
—, *gypsum in Sussex*, 469.
—, *sinking and tubbing at Methley Junction colliery*, 124.
—, *thick coal of Warwickshire*, 515.
Picking-belts, Polmaise collieries, 242.
Pickquick coal-cutting machines, driving headings with, 67 *et seq.*
— — — —, rate of advance, 71.
Pietersburg, South Africa, folding of strata, 544.
Pietre Verdi, Italy, graphite, 683.
Pilkington, Charles, *cage-lowering tables*, 177.
—, *cast-iron tubbing*, 618.
—, *Cook calorimetric bomb*, 288.
—, *liquid air and its use in rescue-apparatus*, 170.
—, *new apparatus for rescue-work in mines*, 277.
—, quoted, 567, 583.
—, *rock-salt deposits at Preesall*, 301.
Pillar-and-stall workings, iron-ores, Spain, Almeria, 702.
— — — —, single-room system compared with, 566.
Pillars, abandoned, underground fires and, 80, 85.
—, single-room system, calculation of dimensions, 562.
Pinar de Bédar, Spain, copper- and lead-ores, 699.
Pitot tubes, measurement of water-gauges by, 60.
Placer-deposits, gold, Korea, 713.
— —, —, Siberia, 714.
Plaster, manufacture of, 328, 452.
—, set ing of, chemistry, 456.
—, varieties of, 456.
Plaster-mills, Tutbury, visit to, N.S., 328.

Platinum associated with gold in placer-deposits, Congo Free State, 724.
— — — — — — — —, Finnish Lapland, 694.
— placer-deposits, Nizhne-Tagilsk, 695.
PLAYFAIR, LYON, quoted, 278.
Pleasley colliery, duplicate fan experiments, 434.
— —, guides for cages, 117.
Pneumatogen, applications, 224, 233.
—, cleaning of, 218.
—, defects in, 223.
—, heating of, ignition of indiarubber pipe, 250.
—, self-generating rescue-apparatus, etc. — Discussion, 250.
—, Tankersley rescue-station, 215.
Pneumonia, deaths from, after breathing carbon monoxide, 6.
POECH, FRANZ, quoted, 141.
POETSCH, H., quoted, 625.
POHLIG cableway for iron-ores, Spain, Almeria, 702.
POLIENOV, B. K., coal-bearing beds in Kuznetsk district, Siberia, 713.
POLLAK accumulators, electric power-station, Grand Hornu, 653.
Polmaise collieries, 237.
— —, section of seams, 244.
— —, — — strata, 239.
Pondoland, South Africa, granite-masses, influence on strata, 546.
Pontoons, conveyance of canal boats by, 376.
Poorten, South Africa, origin of, 549.
POPE & PEARSON, LIMITED, quoted, 205, 208, 209.
Porecka, Servia, gold-fields, 695.
Port St. John, South Africa, granite masses, influence on strata, 546.
Portland cement works, Knight, Bevan & Sturge, Kent, Northfleet, 642.
Posen, Prussia, brown-coal deposits, 673.
Posidonia becheri, Spain, Huelva, pyrites deposits, 705.
— —, upper Silesian coal-measures, 675.
Power, electric transmission of, at works and collieries of Grand Hornu, Belgium, 647.
Poytos copper-mine, Spain, Huelva, 705.
Pramollo, Italy, graphite deposits, 684.
Precsall, Fleetwood, rock-salt deposits, mining, 291.
PREOBRAZHENSKY, P. I., and A. GERASIMOFF, gold-bearing regions of Siberia, 714.
President, x.
—, election, S.I., 153.
Presidential address, 330.
PREST, J. J., *cast-iron tubbing*, 627.
—, *notes on bye-product coke-ovens*, 417.
Preussen II. shaft, Harpen Colliery, Limited, Dortmund, electric winding, 658.
PRIEMEL, KURT, brown-coal deposits of upper Lausitz, Silesia, 673.
Primazka or binding material of detrital deposits, 718.
Primus coal washer, Polmaise collieries, 243.
PRISTER, A., quoted, 553, 554.
Prizes for papers, awards, 329.
— — —, —, N.S., 77.
Props, hydraulic, longwall workings, West Virginia, 559.
—, steel and wood compared, 337.
Prussia, Hesse-Nassau, Holzappel metalliferous belt, 680.
Pumping, costs, saving effected by dam, Methley Junction colliery, 122.
—, electric power and, 337.
—, upper Lausitz, Friedrich Anna mine, 675.
—, — —, Joseph Hermann mine, 674.
—, — —, Louisa mine, Nieder Schönbrunn, 674.
—, water-supplies, 473.
—, — —, costs, 494, 497.
Pumping-engines, developments, 342.
Pumping-plant, tube-wells, permanent, 488.
Pumps, air-lift, description, 492.
—, electric, Belgium, Grand Hornu colliery, 647.
—, —, —, — —, Riedler, 661.
—, —, Boryslaw ozokerite mine, 538.
—, —, Polmaise collieries, 242, 247.
—, —, — —, water for boilers, 240.
Purbeck marble deposits, 471.
PURDY, R., *guides for cages*, 115.
PUTZ, O., ore-deposits of province of Almeria, Spain, 699.
Pyrites, genesis, organic matter and, 682.
—, gold associated with, Servia, 696.
—, gold-deposits and, Siberia, 714, 717.
—, underground fires and, 83, 85, 505.
Pyrites deposits, Germany, Saxony, western Erzgebirge, 680.
— —, Siberia, eastern, Abolesheff bay, 719.
— —, Spain, Huelva, 704.

R.

Railway and canal traffic act, 1888: returns made to Board of Trade in respect of canals and navigations in United Kingdom, quoted, 347.
— — — — —, quoted, 352, 378, 379.
— companies as canal owners, 351.
Railways, electric, Hammersmith and City, current, 634.
RAINE, FREDERICK JAMES, election, N.E., 1.
RAMANN, E., quoted, 677.
RAMSAY, SIR ANDREW C., quoted, 262, 269.

RAMSAY, WILLIAM HENRY, election, N.E., 249.
Rand gold-field, discovery of, 531.
RAND MINES, LIMITED, election, subscribers, N.E., 180.
RANKINE, W. J. M., quoted, 601, 603, 631, 632.
Rasheya, Asia Minor, iron-ores, 710.
RATEAU, A., quoted, 156.
—, *tests of a mine-fan*, 59.
RAWES, F. B., quoted, 458.
RAYNER, FRANK, *improvements required in inland navigation*, 364.
Reden colliery disaster, rescue-work at, 212.
REDMAYNE, R. A. S., *hidden coal-fields of Midlands*, 265.
—, quoted, 577.
Regenerator coke-oven, Koppers, 407.
Regenerators, coke-ovens, reason for adoption, 401.
Regulation of railways act, quoted, 379.
REID, THOMAS, election, S.I., 236.
RENAUD, PAUL, quoted, 223.
Report of council, S.I., 151.
— on rescue-work done by men wearing rescue-apparatus in experimental gallery at Pope & Pearson's collieries, Altofts, March 23rd, 1907, 209.
Repose, angle of, loose strata, 603.
Rescue-apparatus, applications, 2 *et seq.*
— —, cleaning of, 216.
— —, gob-fires and, 518.
— —, helmet and mouthpiece forms compared, 227, 228, 230, 231.
— —, — forms, experiences with, 215.
— —, improvements effected in, 216.
— —, indiarubber appliances, precautions necessary, 220.
— —, injectors, precautions necessary, 219.
— —, liquid air, use in, 2, 170.
— —, necessary features of, 213.
— —, new form, 180.
— —, opinions of wearers, 224.
— —, oxygen charging, precautions necessary, 219.
— —, pneumatogen, 250.
— —, Roberts' early form of, 278.
— —, use and care of, 212.
— —, Weg form, 277.
— —, — —, duration of oxygen supply, 278.
Rescue-station, Tyldesley, 277.
Rescue-work in mines, air-pipes along roads, 3.
— — — —, experimental gallery, Altofts collieries, 205.
— — — —, — —, — —, report on trials at, 209.
— — — —, new apparatus for, 180, 277.
— — — —, training of men, 221.
— — — —, voluntary, necessity for, 228.
Reservoirs, application of ferro-concrete to construction of, 15.
Respirat
Retardin
engine
Rheinpre
electri
RHODES,
—, *minin*
Rhodesia
Rhone, v
RIEDLER
661.
Rietkuil,
at, 543
Rio Tint
RIPPAS, I
A. KH
gold-be
Ripping,
—, stowa
70.
Rise coal
coal, W
RITTINGE
142.
River-v
549.
Rivers, A
ROBERTS,
ROBERTS,
M.I., 8
ROBINSON
180.
Rock-cry
713.
Rock-salt
sall, 29
— — —,
— — —,
— — —,
— — —,
— — —,
— — min
Rodillo or
ROELOFSE
coke-ove
ROGERS, A
Roman wo
— —, Spa
RONALDSO
62.
Roof, di
West V
—, suppor
Rotary he
— kilns, c
ROTARY P
well for
ROTHSCHI
Rotors, G
station,
—, — —
ROUTLEDG
of guide
deep sha
—Discu

ROYAL COMMISSION ON ACCIDENTS IN MINES, quoted, 191.
ROYAL COMMISSION ON CANALS, quoted, 365, 366, 367, 369, 372, 373, 381.
ROYAL COMMISSION ON COAL-SUPPLIES, quoted, 29, 39, 40, 49, 266.
ROYAL COMMISSION ON MINES, quoted, 233, 333.
Royalties, thick and thin seams, comparison, 91.
Royalties, thick and thin seams, tonnage-basis, 102.
Rubber-ropes, use with wire-rope guides, 106, 107.
RUSSELL, ARCHIBALD, LIMITED, quoted, 235, 237.
Russia, Nizhne-Tagilsk, manganese and other ore-deposits, 695.
Ruwe, Congo Free State, auriferous deposit, 722, 724.

S.

Sadisdorf, Germany, minerals associated with wolframite, 683.
Safety-lamps, new reflector for, 281.
— —, Polmaise collieries, 241, 246.
St. Ann gold-mines, Servia, Deli-Iovan, 696.
St. Blasius, Baden, nickeliferous magnetic pyrites, 677.
Sakhalin coal-field, Manchuria, comparison with Fushun coal-field, 712.
SALISBURY, MARQUIS OF, quoted, 490.
SALMON FISHERIES COMMISSION, quoted, 379.
SALMOND, JAMES, quoted, 235.
Salt-deposits, Asia Minor, 709.
— —, Fleetwood, Preesall, 291.
— —, Middlesbrough, discovery of, 666.
Sampling for analysis, coal, 283.
SANDBERG, C., notes on structural geology of South Africa, 540. – Discussion, 556.
Sandwell Park colliery, method of working, 516.
— — —, south Staffordshire coal-field extensions, 44.
— — —, thick coal-seam at, 502.
SANER, J. A., *improvements required in inland navigation*, 373.
—, quoted, 366.
Santa Catalina manganese-mine, Spain, Huelva, 707.
Sapalsky manganese-mine, Nizhne-Tagilsk, 695.
Sardinia, Italy, Cagliari, tungsten-ores, 686.
—, —, Castello di Bonvei, azurite-deposit, 685.
SARLIN, E., quoted, 693.
Satin-spar, occurrence in gypsum, 451, 471.
SAWYER, A. R., New Rand gold-field, Orange River Colony, 530. —Discussion, 531.
—, quoted, 541.
—, *structural geology of South Africa*, 557.
Saxony, Halle-an-der-Saale, kaolin-deposits, 676.
—, tungsten-ores, 682.
—, western Erzgebirge, pyrites-deposits, 680.
Schaapplaats, Orange River Colony, bore-hole, 531.
Scheelite, Genna-Gurèu antimony-mines, 686.
—, Sardinia, analyses, 687.
SCHEMBER, FRIEDRICH, election, M.G., 170.
Scheuerloch, Baden, nickel-ore mines, 678.
Schlägel-und-Eisen III. and IV. collieries, hauling arrangement at face, 663.
Schlamm, production of, in coal-washers, 145.
SCHMEISSER, C., mineral-resources of Asia Minor, 709.
SCHMIDT, —, quoted, 625.
SCHMIDT, ALBERT, stanniferous deposits of Fichtelgebirge, Bavaria, 679.
SCHNABEL, LEBERECHT FERDINAND RICHARD, election, N.E., 179.
Schönlind, Bavaria, stanniferous lodes, 679.
Schuplja Stena, Servia, adit, mercury mine, 698.
SCHWARTZKOPFF COAL-DUST FIRING SYNDICATE, quoted, 339.
Schweighausen, Prussia, metalliferous belt, 680.
Scientific mining in Barnsley district, importance of, 90. —Discussion, 99.
Sclit or slaty coal, 243.
Screening fine coal, difficulties, 143.
Screening-plants, improvements in, 344.
— —, Polmaise collieries, 242, 247.
Screens, dust from, 254, 344.
—, — —, Courrières collieries, 137.
—, hydraulic, for fine coal, 143.
—, —, production of schlamm and, 146.
SEATON, A. F., quoted, 584.
Secretary, xi.
Seehaus, Bavaria, tin-mines, 679.
SEELEY, H. G., quoted, 540.
Selemja, Siberia, gold-placers, 716.
Semi river, Siberia, gold-placers, 717.
Serena, Spain, Almeria, iron-ores, 702.
Servia, Avala hill, mercury-ores, 697.
—, gold-fields, 695.
Servian-French mining glossary, 697.
Sesia-Val di Lanzo, Italy, graphite-deposits, 684.
Sevenich, Prussia, metalliferous belt, 680.
SEVERN AND CANAL CARRYING COMPANY, quoted, 375.
SEWAGE DISPOSAL COMMISSION, quoted, 379.

Seward peninsula, eastern Siberia, gold-placers, 719.
Seymour, H. W., *notes on bye-product coke-ovens*, 422.
Shaft-sinking, freezing-process, 197, 251.
— —, — —, Monkwearmouth, 275.
— —, Polmaise collieries, 237, 244.
— —, rock-salt deposits, Preesall, 293.
Shaft-tubbing, cast-iron, formula for thickness, 567.
Shafts, Boryslaw ozokerite-mine, 537.
—, brown-coal mines, upper Lausitz, 674, 675.
—, deep, guides for cages for, 104.
—, Grand Hornu colliery, 656.
—, main, electric winding for, 150.
—, Pleasley colliery, 117.
—, Polmaise collieries, 237, 244.
—, Wearmouth colliery, 275.
—, Wombwell Main colliery, 116.
Shamrock colliery, rescue-work, results of practices, 213, 229.
Shamrock rescue-apparatus, efficiency, 224.
— — —, improvements, 225.
Sharpness Dock Company, quoted, 383.
Sharpness New Docks, quoted, 375.
Shelton Coal and Iron Company, Limited, clamp for guide-ropes, 113.
Shelton colliery, Cockshead seam, coal and gas outbursts, 313.
Shot-drilling method of boring, 482.
— — — — —, loss of shot in fissures, 498, 499.
Shot-firing, explosions and, 129, 131, 132.
— —, Midlands, decrease in, 132.
— —, suggestions regarding, 127, 187, 191.
— — in main haulage-ways, cause of explosion, 135.
— — — — — —, dangers, 128, 129, 131, 132, 134.
Shrewsbury coal-field, extensions, 41, 48.
— — —, strata, 33.
Shropshire coal-field, character of seams, 48.
— — —, gob-fire, 78.
— — —, Symon fault, 265.
Siberia, Akmolinsk, coal-fields, 526.
—, gold-bearing regions, 714.
—, Kuznetsk, coal-fields, 713.
Sicily, north eastern, mineral deposits, 687.
Siemens-and-Halske generators, electric power-plant, Boryslaw, ozokerite-mine, 536.
Sierra Almagrera, Spain, Almeria, ore-deposits, 702.
— de Bédar, Spain, geology, 699.
— — —, —, ore-deposits, 701.
Signalling, Preesall salt-mine, 297.
Silesia, upper, coal-measures, posidonia becheri in, 675.
—, — Lausitz, brown-coal deposits, 673.
Silver, ou… 697.
Silver-bea… 690.
— — —, S…
— — —, S…
Silver min…
Silver-ores…
— —, Kor…
Simcock, …
—, *outbur…*
Simonis, …
in rescue…
Simonis, C…
rescue-a…
Simplex …
Cross, 3…
Simplex C…
Compan…
Single-roo…
tion of …
thick se…
Sinking an…
colliery.
— through…
yellow s…
Discussi…
Sinope, As…
Sirocco fa…
collieries…
Sivas, Asi…
Skatamark…
693.
Slate-mini…
Slater, …
N.E., 18…
Sliding-tro…
sion, 200…
Smart, Ro…
Smith, …
guardian…
—, *hidden…*
264.
—, *thick co…*
Smith, An…
Smith, Ga…
25.
Smith, H. …
515.
Smith, Sy…
bomb, 28…
Smith, Th…
Smith, T. …
Smithurst…
Smyrna, A…
710.
Sneddon, …
Sneddon, …
Sneddon, …
cillor, S.…
Sneyd colli…
gas outbu…
Society of…
Society of…
456.

Sodium chloride, formation in nature, 302.
— peroxide, use in determining calorific values, 285.
Songuldac, Asia Minor, coal-shipping port, 711.
SOPWITH, S. F., *boilers for colliery purposes*, 167.
—, *Hanley cage-guardian*, 168.
—, *hidden coal-fields of Midlands*, 268.
S'Ortu Beciu mine, Sardinia, tungsten-minerals, 686.
South Africa, Alps and, structural geology compared, 552.
— —, gold-fields, Witwatersrand and New Rand compared, 534.
— —, labour question, 533.
— —, Orange River Colony, New Rand gold-field, 530.
— —, structural geology, notes on, 540.
— —, — —, summary of conclusions, 556.
— Kirkby colliery, wire-rope guides, clearance, 114.
SOUTH LEVEL DRAINAGE AND NAVIGATION COMMISSIONERS, quoted, 354, 355.
SOUTH WALES INSTITUTE OF ENGINEERS, quoted, 330, 331.
SPAARFEUERUNGS GESELLSCHAFT, Düsseldorf, quoted, 649.
Spain, Almeria, ore-deposits, 699.
—, Huelva, pyrites deposits, 704.
SPEIR, DAVID, election, S.I., 236.
Spektralny gold-mine, Siberia, 715.
Square-work system of working thick coal, 520.
Staffordshire, north, coal and gas outbursts, 313.
—, —, coal-fields, 30.
—, —, — —, extensions, 41, 48.
—, —, coal-measures, divisions, 30, 31.
—, —, underground fires, 85.
—, south, and east Warwickshire coal-fields, correlation, 271.
—, —, coal-fields, extensions, 28, 45, 46, 263.
—, —, coal-measures, divisions, 32.
—, —, gob-fires and methods of working, 524.
—, —, ten-yards seam, method of working, 513.
Stanniferous deposits, Bavaria, Fichtelgebirge, 679.
Starunia, Austria, ozokerite, 535.
STATON & COMPANY, J. C., quoted, 328.
Stators, Grand Hornu colliery, electric power-station, generators, 651, 652.
—, — — —, winding-motors, 658.
Steam-consumption, collieries, economies effected in, 339.
Steam-pipes, electric power-station, Grand Hornu, 650.
— —, — — —, Park Royal, 638.
STEART, F. A., quoted, 550.
STEAVENSON, A. L., *liquid air and its use in rescue-apparatus*, 2.
STEAVENSON, C. H., *treatment of dust in mines*, 258.
Steel props and girders, economies effected by, 337.
Steel-rail guides for cages, 110.
— — — — —, costs, 111.
Steel rails, basic, use on North-eastern railway, 666.
STEPHENSON, GEORGE, quoted, 386.
Sterra, Sicily, lead-and-zinc ores, 688.
STEVENSON, H., *Courrières explosion*, 127.
STEVENSON, THOMAS, *heading by longwall machines*, 159.
STOBBS, J. T., *Courrières explosion*, 327.
—, *outbursts of coal and gas*, 320.
—, quoted, 28, 268.
Stokers, mechanical, boilers, electric power-station, Grand Hornu, 649.
—, —, —, — — —, Park Royal, 641.
STOKES, A. H., *Courrières explosion*, 128.
—, quoted, 125, 307, 308.
STONE, TOM, election, M.G., 277.
Stour valley coal-field, extensions, water-bearing strata, 48.
STRAFFORD COLLIERIES COMPANY, LIMITED, quoted, 209.
STRAHAN, AUBREY, quoted, 40.
Strata, loose, angles of repose, 603.
Strectly bore-hole, coal-measures at, 45, 262, 271.
Stretcher for use in mines, 162.
STRUBEN, H. W., *New Rand gold-field*, 531.
Structural geology of South Africa, notes on, 540.—Discussion, 556.
STRZELECKI, PERCY, barometer, thermometer, etc., readings for 1906, 725.
STUART, DONALD M. D., *explosion at Wingate Grange colliery*, 183.
STUTZER, O., Gellivaara and Kiirunavaara iron-ores, northern Sweden, 69.
—, graphite-deposits in Lapland, 693.
Styggedalen, Norway, barytes-vein, 690.
Su-Suergiu antimony-mine, Sardinia, 686.
Sub-Wealden boring, Netherfield, 449, 452.
SUB-WEALDEN GYPSUM COMPANY, LIMITED, quoted, 449.
Subjects for papers, xviii.
Subsidence, mining leases and, 336.
— phenomena, gypsum-mines, Sussex, 469.
Suction-gas engines, electric winding and, 54.
— — plants, air-lift pumps for water-supply, 494, 495.
— — —, working costs, 341.
Sulaki river, Siberia, gold-placers, 717.
Sulatkitkan river, Siberia, gold-placers, 717.
SULLIVAN electric chain coal-cutting machine, Gay Coal and Coke Company, 563.
Sulphur, recovery from anhydrite, 458.

Sultanchaïr, Asia Minor, pandermite deposits, 709.
SULZER-CAREIS valves, engines, electric power-station, Grand Hornu, 650.
Superheaters, Babcock & Wilcox boilers, Park Royal power-station, 639.
—, Hering, boilers, electric power-station, Grand Hornu, 649.
Surface-condensing, advantages, 340.
Surface damages, mining leases and, 336.
— ownership, small holdings, minerals and, 51.
Sussex, gypsum deposits 449.
SUTCLIFFE, R., importance of scientific mining in Barnsley district, 90.—Discussion, 99.
—, *notes on bye-product coke-ovens*, 421.
—, *sinking by freezing-process*, 252.
—, *treatment of dust in mines*, 259.
Svappavaara 693.
SVEDELIUS,
SVENONIUS,
Sveta-Varv
SWALLOW, poses.—
—, *thick co*
Sweden, no avaara ir
Switchboar Grand H
—, — — —
—, Polmais
—, — —, u
Switzerlan galena, 7
Synchroniz ing, Park

T.

Tacheograph, Karlik, electric winding-engines, Grand Hornu colliery, 661.
Takhtyga river, Siberia, gold-placers, 715.
Talc-deposits, Korea, 713.
Tallberget, Lapland, graphite-deposits, 693.
Tamarack copper-mines, depth of workings, 266.
TANGANYIKA CONCESSIONS, LIMITED, quoted, 721.
TANGYE engine, coal-crushing plant, Clay Cross, 388.
Tankersley rescue-station, duration-tests, results, 233.
— — —, experience gained, 212.
— — —, rescue-work trials by men from, 209.
Tantalum electric lamps, Preesall salt-mine, 297.
Tar, recovery of, coking-plant, Clay Cross, 396.
Taratan or horse-gin, 527.
Tarbrax electric winding-plant, test, 52.
TATE, W., quoted, 123, 568, 571.
TAYLOR, HUGH FRANK, election, M.G., 290.
TAYLOR, NEIL, election, N.E., 179.
Tectonic influences, geology, South Africa, 540.
TELFORD, THOMAS, quoted, 380.
Temperature rise with depth, 266.
Terrace-gold, placer deposits, Finnish Lapland, 694.
TEUTENBERG, WILLIAM, election, N.E., 250.
Thames and Medway canal, severing of, 353.
THAMES CONSERVANCY BOARD, quoted, 378.
THAMES VALLEY DRAINAGE COMMISSIONERS, quoted, 353.
Tharsis, Spain, ore-deposits, 705.
Thermomet
Thick coal 528.
— —, singl 558.
— — of W 513.
— — — —
Thin coal, tions affe
THIRKELL, *district*,
THOMAS, G *in inland*
THOMPSON, compress Ingersoll —Discuss
THOMPSON, 250.
THOMPSON, at Prees operation 298.
THOMPSON, *cate fans*
—, quoted,
—, *use an apparatu*
THOMSON,
THOMSON, —Discuss
THOMSON, president
—, *heading*
Thunilthan placer, 7
Tidal varia sinking,
Timber for
— in goave
Timbering, 537.

Timbering, Courrières collieries, 309.
—, shafts, Polmaise collieries, 239.
Timmis, G. H., quoted, 266.
Timok, Servia, gold-fields, 695, 697.
Tinsbury colliery explosion, cause, 128, 184, 195.
Tin-ores, Congo Free State, Katanga, 722.
Tinstone, Bavaria, Fichtelgebirge, 679.
Tirpersdorf, Saxony, tungsten-ores, 682.
Toba or ferruginous conglomerate, 706.
Todd, David, quoted, 235.
Todd, J. T., *Courrières explosion*, 127.
Todtmoos, Baden, nickel-ore mines, 678.
Toit, A. L. du, quoted, 547.
Tokad, Asia Minor, copper-ores, 711.
Torque, coal-cutting machines and, 446.
Traag, Norway, blende- and galena-deposits, 689.
Trades disputes act, quoted, 334.
Transformers, electric power-station, Grand Hornu, 653.
Travelling-troughs, haulage at face, 663.
Treasurers, xi.
Trebizonde, Asia Minor, copper-ores, 711.
Tredegar colliery explosion, watering, effect, 134.
Trent and Mersey canal, 352.
Troitschendorf, Silesia, brown-coal deposits, 674.
Trough coal-washers, 139.
Troussart, E., electric transmission of power at works and collieries of Grand Hornu, Belgium, 647.
Truskawiec, Austria, ozokerite, 535.
Tshentsintai coal-mine, southern Manchuria, 712.
Tubbing, cast-iron, bitumen-asphalt preservative, 620.
—, — —, casting imperfections, 598.
—, — —, collapse versus crushing, 584.
—, — —, composition for preserving, 122, 580.
—, — —, corrosion, effect of back-lining, 579.
—, — —, —, rate of, 624.
—, — —, corrosive energy, 607.
—, — —, earth-pressures, 600.
—, — —, formula for thickness, 123, 567, 664.
Tubbing, cast-iron, formula for thickness, application of formula for thin cylinders, 569, 581.
—, — —, — — —, corrosion and, 570 *et seq.*
—, — —, — — —, deduction without calculus, 607.
—, — —, life of, 570.
—, — —, Methley Junction colliery, 120.
—, — —, Preesall salt-mine, 293.
—, — —, ribs and flanges, 583 *et seq.*
—, — —, variation in strength of raw material, 571.
—, — —, wedging, disadvantages, 591.
—, — —, —, iron wedges, use criticised, 628.
—, — — and steel compared, 620.
—, shafts, pressure on, 567.
Tube-mills, grinding cement-clinker in, Knight, Bevan & Sturge works, 644.
Tube-wells, artesian bored, water supplies, 473.
— —, driven, 480.
— —, testing of, 483.
Tubes, artesian wells, 476.
Tubs, difficulties due to non-conformity in sizes, 96.
—, watering of, 254.
Tungsten-ores, Italy, Sardinia, Cagliari, 686.
— —, Saxony, 682.
Tunnel driving, freezing-process, U.S.A., 197.
Tuollavaara, Sweden, iron-ores, 690, 691.
Turbine engine, comparison with reciprocating engines for generating electricity, 54.
— —, Polmaise collieries, 240.
— —, — —, ventilating fan, 241.
— —, steam-consumption, 339.
Turbine-pumps, Polmaise collieries, 242.
Turner, Thomas, *tests of a mine-fan*, 58.
Tutbury gypsum-mines and plaster-mills, vist to, N.S., 328.
Tutz-Chöllü, Asia Minor, salt deposits, 709.
Tutz-Kioi, Asia Minor, salt-deposits, 710.
Tweddell, George, election, N.E., 250.
Tyldesley rescue-station, 277.

U.

United Alkali Company, Limited, Preesall salt-mine, 291.
United Kingdom, coal output, 340.
— —, — — and fatal accidents, 332.
— —, — — per man, 565.
— —, deaths from falls of roof and side, 333.
— —, navigable inland waterways, 347.
U.S.A., freezing process, applications, 197.
U.S.A., Michigan, Tamarack copper-mine, depth of workings, 266.
—, Pittsburg, coal-output per man, 565.
—, West Virginia, coal-mining, markets, 566.
—, — —, longwall workings, adaptation of, 558.
Unwin, W. C., quoted, 584, 585, 596.

V.

Vacha river, Siberia, gold-placers, 715.
Val d'Orco, Italy, graphite-deposits, 685.
Val di Lanzo, Italy, graphite, 683.
Valleys, Alpine, origin of, 552.
Van Rhynsdorp, South Africa, geology, 547.
Van 't Hoff, J. H., quoted, 457.
Vena contracta, fan orifices and, 61.
Ventilation, air-splitting, coal-dust explosions and, 124.
—, Boryslaw ozokerite-mine, 538.
—, cessation of working and, 444.
—, coal-dust question and, 184.
—, Courrières collieries, criticism of, 308.
—, duplicate fans, 431.
—, extensive workings, 343.
—, fan-tests, 58, 155.
—, Grand Hornu colliery, 662.
—, gypsum-mines, Sussex, 467.
—, Polmaise collieries, 241, 246.
—, Preesall salt-mine, 297.
—, restoration after explosions, 222.
—, reversal by gob-fire, 81.
Vernon-Harcourt, L. F., *improvements required in inland navigation*, 365.
Veta, Servia, mineral deposits, 696.
Vice-presidents, election, S.I., 153.
— —, list, x.
Vickers, Sons & Maxim, Limited, Erith artesian tube well, 487.
Viminacium, Roman workings, gold-fields, Servia, 696.
Virgen de la Peña, Spain, Huelva pyrites-deposits, 707.
Virginia, West, adaptation of longwall method of working coal, 558.
Vogt, J. H. L., blende- and galena-deposits of Traag, Norway, 689.
—, quoted, 704.
Voigtland, Saxony, tungsten-ores, 682.
Voit, F. W., quoted, 547.
Vratarnica, Servia, gold-fields, 697.
Vredefort granite-mass, denudation, 549.
— — —, influence on strata, 542.
— mountain-land, South Africa, geology, 541.

W.

Waddle fans, duplicate, experiments with, 434.
Wachorn, —, quoted, 378.
Wain, E. B., *Courrières explosion*, 303, 326.
Waley, Frederick George, election, N.E., 1.
Walker, G. Blake, quoted, 215.
Walker, Henry, election, N.E., 250.
Walker, Sydney F., *application of duplicate fans to mines*, 434.
—, quoted, 578.
—, *thick coal of Warwickshire*, 517.
Walker, W., *guides for cages*, 114.
—, *mining in Barnsley district*, 102.
—, quoted, 209.
Wallsend colliery, effect of mine-waters on cast-iron, 577.
Ward, Thomas H., *thick coal of Warwickshire*, 523.
Wardle, Robert, election, N.E., 180.
Warwickshire coal-field, east, and south Staffordshire coal-fields, correlation, 271, 513.
— — —, extensions, 43, 271.
— — —, strata, 32.
— — —, thick coal-seam, 502.
— — —, — — —, characteristics, 528.
— — —, — — —, method of working, 507.
Washington chemical works, establishing of, 665.
Wassel Grove colliery, coal-measures, 45.
Waste-gases, coke-ovens, beehive, utilization, 386.
— —, — —, regenerators and, 402, 412.
Waste-heat coke-ovens, Koppers, 403.
Water, bye-product coking-plant, Clay Cross, quantity required, 396.
—, cost of, 474.
—, from bore-hole, Lancashire, Preesall, 292.
—, gypsum-mines, difficulties with, 461.
—, shaft-sinking, Polmaise collieries, 238.
—, underground supplies, temperature, 474.
— for boilers, gypsum-mines, distillation, 463.
— — colliery boilers, 339.
— — — —, purification of, costs, 339.
Water-gauges, ventilation, extensive areas, 343, 344.
— —, —, Grand Hornu colliery, 662.
— —, —, measurement by Pitot tubes, 60.
Water-rights, canal authorities and, 353.
Water-softening plant, Park Royal power-station, 639.
Water-sprays, gob-fires and, 518.
Water-supplies, list of strata yielding, 477.
— — by means of artesian bored tube-wells, 473.—Discussion, 497.
— — — pumping, 473.
— — from bore-holes, methods of increasing, 484.
Water-tube boilers, economies effected by, 338.
Waterhouse, Frank H., election, M.I., 208.
Waterhouse, M. W., *thick coal of Warwickshire*, 518.
Watering in mines, 190 *et seq.*

ıg in mines, coal-dust treatment, ıystem, 254.
-, effect in hot pits, 188.
-, — on roads, 306, 333.
-, explosions and, 129, 131, 134,
-, injurious effects, 257 *et seq.*
rays, inland, England and Wales,
avigation, classification, 356.
—, improvements required, me- suggested, 355.
ı, Edward, *thick coal of Warwick-* 526.
ı, Percy Houston Swann, elec- M.G., 277.
ı, Thomas, Jun., election, N.E.,
Hubert, election, N.E., 250.
outh colliery, shafts, 275.
scue-apparatus, trials, 209.
henk, E., nickeliferous magnetic es of Black Forest, Baden, 677.
ed, 684.
ıstadt, Bavaria, tin-mining, 679.
artesian, 473.
ace, contamination of, 473, 475.
nbach, F., quoted, 680.
, Prussia, Gute Hoffnung mine, dykes, 680.
Iam Corporation, water-supply orks, 479.
Riding collieries, cage-lowering ı, 174.
-, visit to, M.I., 205.
ghouse generators, electric r-station, Knight, Bevan & Sturge ıt works, 646.
alia, coal-measures, posidonia ri in, 675.
, Bruno, Huelva pyrites-deposits, , 704.
cliffe Silkstone Colliery any, Limited, quoted, 209.
netal capels for winding-ropes,
s works, Birmingham, artesian well, 487.
od collieries, duplicate Capell ıt, 438, 439.
en, air-lift pumping in bore-hole ater-supply, 485.
t, Henry, quoted, 449.
m-Thomson calorimeter, 285.
ms, Foster, election, N.E., 180.
ms, Isaac, election, N.E., 179.
ms, Thomas, election, M.G., 290.
, Henry Stevenson, election, 250.
, J. R. R., *mining in Barnsley* ıt, 99.
ed, 209.
and care of oxygen-breathing atus, 222.
, William, election, N.E., 250.
Winborn, A. T., *use and care of oxygen-breathing apparatus*, 223.
Wind-gauges, experiments at Forth bridge, 62.
Winding, cage-lowering tables, New Moss colliery, 174.
—, cages, safety device for, 164, 168.
—, deep shafts, 343.
—, electric, determination of acceleration, 657.
—, —, emergency arrangements, Grand Hornu colliery, 653.
—, — and steam compared, 53 *et seq.*
—, Preesall salt-mine, 296.
Winding-engines, Boryslaw ozokerite-mine, 537.
— —, electric, Grand Hornu colliery, 656.
— —, —, safety-appliances, Grand Hornu colliery, 660.
— —, gas, Sub-Wealden Gypsum Company, Limited, 465.
— —, improvements in, 339.
— —, Polmaise collieries, 240, 246.
Winding-plant, Grand Hornu colliery, 657.
— —, gypsum-mines, Sussex, 467.
— —, Tarbrax electric, test, 52.
Winding-ropes, deep-mining, 343.
— —, locked-coil, Wombwell Main colliery, 116.
— —, Polmaise collieries, 240, 246.
Winding torques, effect of acceleration on, 52.
Wingate Grange colliery explosion, 130, 304, 305, 309.
— — — —, cause, 134.
— — — —, discussion on, 183.
Winstanley, G. H., *cage-lowering tables*, 178.
—, *liquid air and its use in rescue-apparatus*, 171.
Wire-rope guides for cages, 104, 111.
— — — — —, cost, 112.
— — — — —, effect of safety-device on, 166.
— — — — —, fixing of, 105.
— — — — —, — —, clamp for, 113.
— — — — —, life, 105, 111.
— — — — —, vibration, cause, 115.
Witley colliery, coal-field extensions, 266.
Witwatersrand, folding of strata, 552.
—, geology, 530.
Wolframite, Saxony, 682.
—, —, minerals associated with, 683.
Wombwell Main colliery, winding-shaft, equipment, 116.
Wonliarliarsky, W. von, quoted, 719.
Wood, E. Seymour, sinking through magnesian limestone and yellow sand by freezing process at Dawdon colliery, near Seaham Harbour, county Durham.—Discussion, 197, 251.
—, *treatment of dust in mines*, 257.

Wood, George, election, N.E., 180.
Wood, Nicholas, quoted, 201.
Wood, Robert, election, N.E., 179.
Wood, W. O., quoted, 567, 579, 580, 591, 592.
Woodworth, B., *gob-fire in Shropshire mine*, 84.
Worcester, east, water-works, pumping-plant, 492.
Wordsworth, T. H., cage-lowering tables at New Moss colliery, 174.—Discussion, 177.
Working, methods of, Boryslaw ozokerite-mine, 537.
—, — —, Freehold colliery, 79.
—, — —, heading by longwall machines, 69.
—, — —, iron-ores, Spain, Almeria, 702.
—, — —, Lens collieries, No. 7 pit, 198.
—, — —, metal-mines, Spain, 700.
—, — —, rock-salt, Preesall, 295.
—, — —, Siberia, Akmolinsk, 527.
—, — —, thick coal of Warwickshire, 507.
Working foreign
Workmen arising
— compe
Worthin boilers, Hornu,
— —, Po
Wrought 577.
Wüst, E an-der-
Wyken c
— —, thi
— —, thi
Wynne, 326.
—, *gob-fi*
—, *outbu*
Wynne, M.G.,
Wynne, 472.

Y.

Yakovlev, N., manganiferous and other ore deposits of Nizhne-Tagilsk, Russia, 695.
Yassnyi gold-placer, Siberia, 718.
Yavorovsky, P., E. Ahnert, M. M. Ivanoff, A. Khlaponin and P. Rippas, gold-bearing regions of Siberia, 714.
Yorkshir in, 90.
—, coal-fi
—, south seams,
—, —, measur

Z.

Zeia river, Siberia, gold-placers, 715.
Zell, Prussia, metalliferous belt, 680.
Zhivak or native gold amalgam, 696.
Zinc, output, Servia, Kucajna mines, 697.
Zinc-blende, Norway, Traag, 689.
— —, Prussia, Hesse-Nassau, 680.
— —, Saxony, western Erzgebirge, 681.
Zinc-blen
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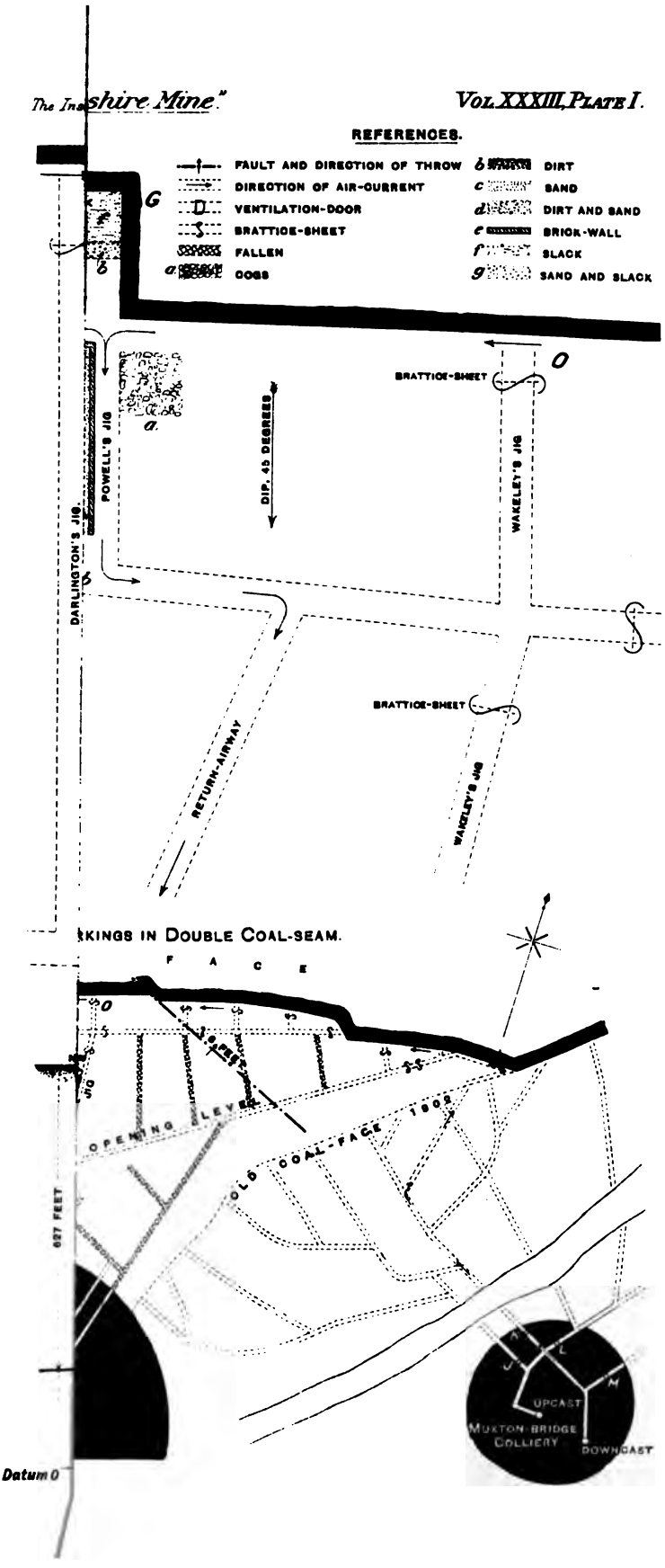
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BRICK-WALL
SLACK
SAND AND SLACK
BRATTICE-SHEET
POWELL'S JIG
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FACE
OPENING SLEVE
OLD COAL-FACE 1903
627 FEET
UPCAST
MUXTON-BRIDGE COLLIERY
DOWNCAST
Datum 0

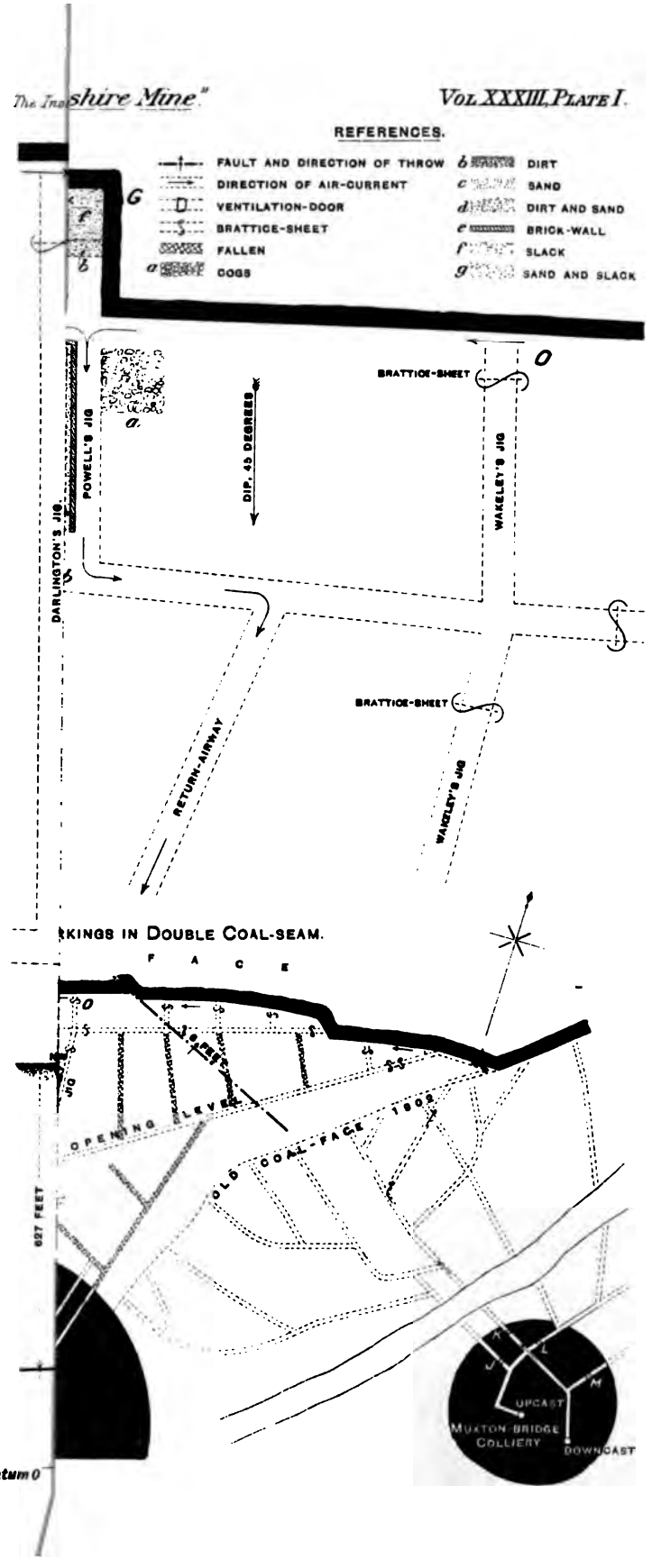
Wood, George, election, N.E., 180.
Wood, Nicholas, quoted, 201.
Wood, Robert, election, N.E., 179.
Wood, W. O., quoted, 567, 579, 580, 591, 592.
Woodworth, B., *gob-fire in Shropshire mine*, 84.
Worcester, east, water-works, pumping-plant, 492.
Wordsworth, T. H., cage-lowering tables at New Moss colliery, 174.—Discussion, 177.
Working, methods of, Boryslaw ozokerite-mine, 537.
—, — —, Freehold colliery, 79.
—, — —, heading by longwall machines, 69.
—, — —, iron-ores, Spain, Almeria, 702.
—, — —, Lens collieries, No. 7 pit, 198.
—, — —, metal-mines, Spain, 700.
—, — —, rock-salt, Preesall, 295.
—, — —, Siberia, Akmolinsk, 527.
—, — —, thick coal of Warwickshire, 507.
Working of mines, notes of colonial and foreign papers on, 673.
Workmen's clubs, collieries, benefits arising from, 345.
— compensation act, quoted, 334.
Worthington pumps, feed-water, boilers, electric power-station, Grand Hornu, 650.
— —, Polmaise collieries, 242, 246.
Wrought iron, effect of mine-water on, 577.
Wüst, Ewald, kaolin-deposits of Halle-an-der-Saale, Saxony, 676.
Wyken colliery, Ell coal-seam at, 504.
— —, thick coal-seam at, 502.
— —, thickness of coal at, 263.
Wynne, F. H., *Courrières explosion*, 309, 326.
—, *gob-fire in Shropshire mine*, 84.
—, *outbursts of coal and gas*, 324.
Wynne, George Reynolds, election, M.G., 282.
Wynne, T. Trafford, quoted, 328, 458, 472.

Y.

Yakovlev, N., manganiferous and other ore deposits of Nizhne-Tagilsk, Russia, 695.
Yassnyi gold-placer, Siberia, 718.
Yavorovsky, P., E. Ahnert, M. M. Ivanoff, A. Khlaponin and P. Rippas, gold-bearing regions of Siberia, 714.
Yorkshire, Barnsley district, mining in, 90.
—, coal-fields, extensions, 39.
—, south, Barnsley district, workable seams, 92.
—, —, workable seams, lower coal-measures, 98.

Z.

Zeia river, Siberia, gold-placers, 715.
Zell, Prussia, metalliferous belt, 680.
Zhivak or native gold amalgam, 696.
Zinc, output, Servia, Kucajna mines, 697.
Zinc-blende, Norway, Traag, 689.
— —, Prussia, Hesse-Nassau, 680.
— —, Saxony, western Erzgebirge, 681.
Zinc-blende, Sicily, 680.
Zinc-ores, ancient mining and, 708.
Zinnwald, Saxony, tungsten-ores, 683.
Zittau, Saxony, brown-coal deposits, 674.
Zlot-Brestovac, Servia, gold associated with chalcopyrite, 697.
Zwartebergen-poort, South Africa, folding of strata, 550.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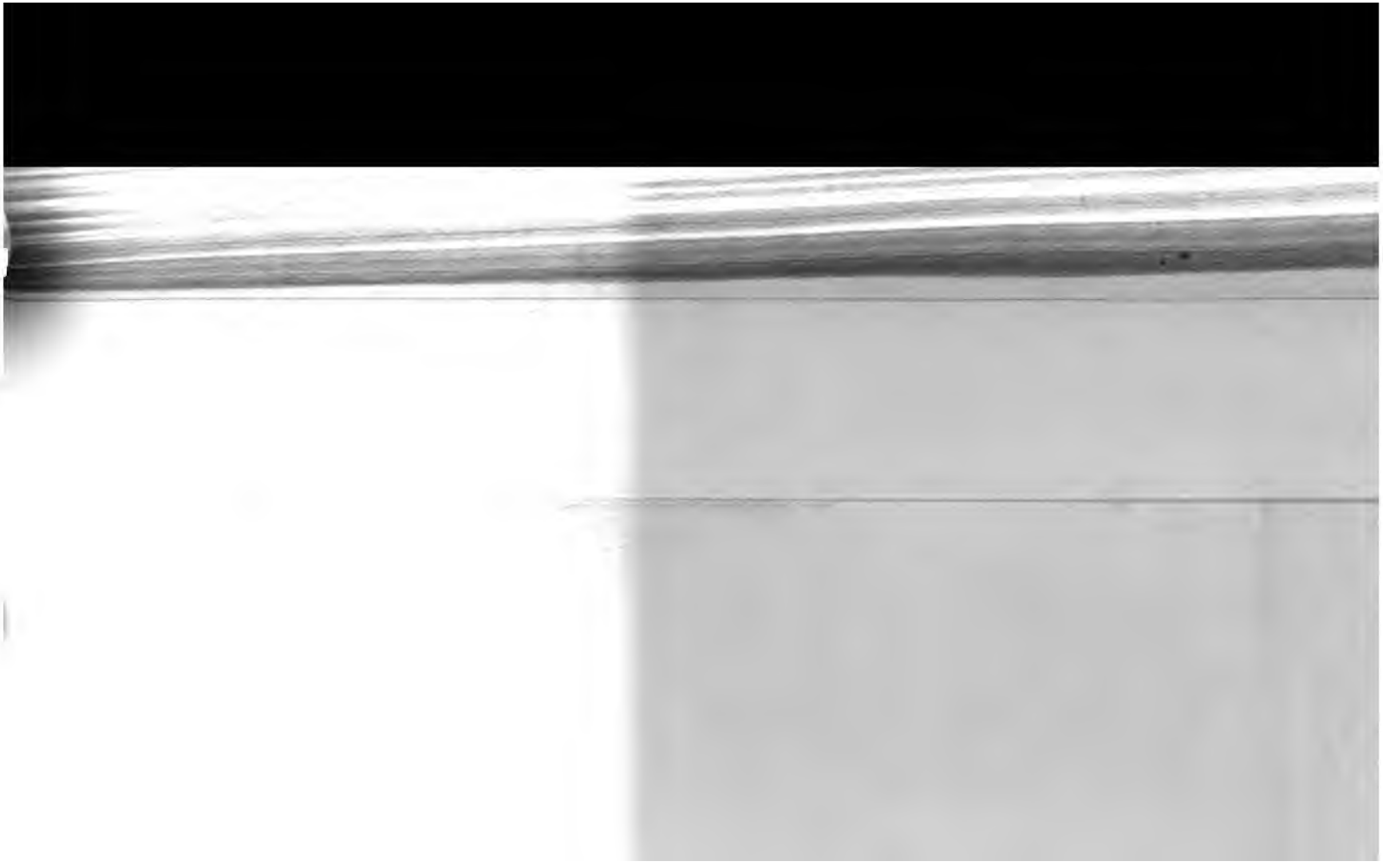
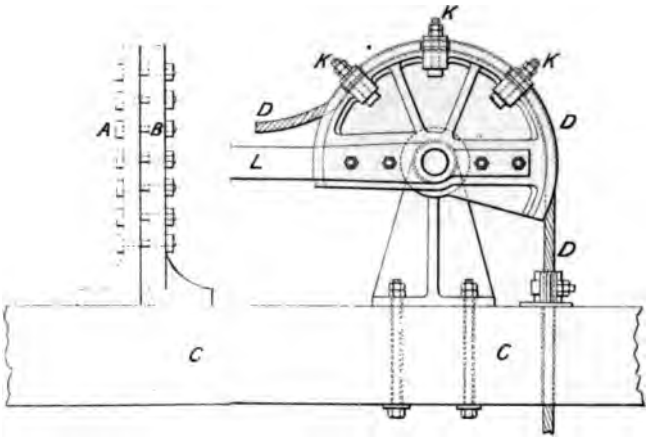


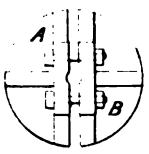
FIG. 1.—SIDE ELEVATION ...ATION OF WEIGHTED QUADRANT.



RUNNER OR SHOE.

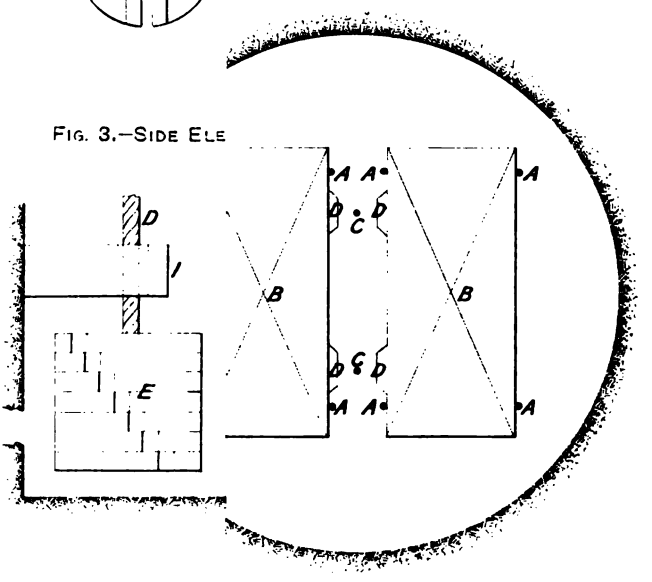
FIG. 2.—PLAN OF CL...

Scale. 1 Foot to 1 Inch.



...LAN OF SHAFT, 16 FEET IN DIAMETER.

FIG. 3.—SIDE ELE...



Scale, 2 F... Scale, 6 Feet to 1 Inch.

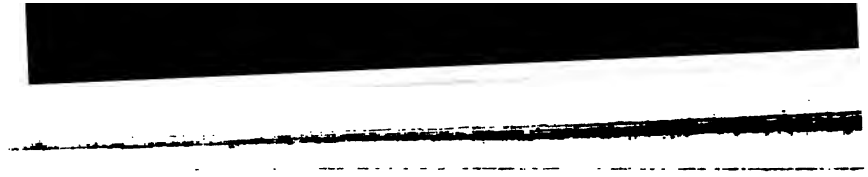
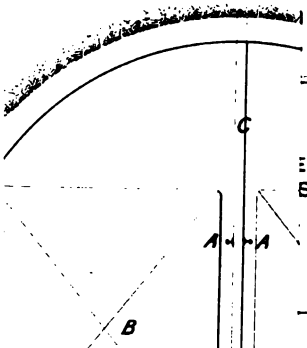


Fig. 8.—Plan of Shaft, 18 F... fitted with Steel-Ra...

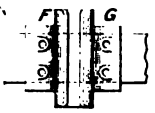


...R.

Scale, 6 Feet to 1 ...

—Plan of Cage-shoe Steel-rail Guides.

Elevation of Cage-shoe Steel-rail Guides.



...levation ... Guides.

Fig. 14.—Elevation of Steel-rail Guide.

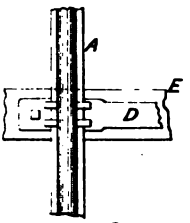


Fig. 15.—Plan of Steel-rail Guide.

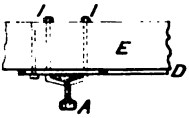
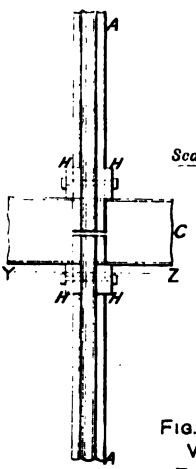


Fig. 12.—Elevation of ... of Steel-rail Guides.



Scale, 2 Feet to 1 Inch.

Fig. 20.—E... Clamped E... Guide in H...

Fig. 22.—Elevation of Weighted End of Rope Guide in Sump.

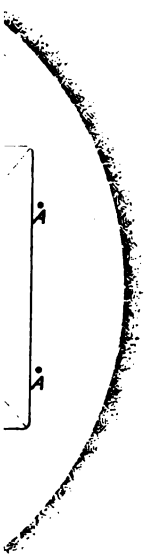


Fig. 13.—Sectional Plan on Line YZ of Fig. 12.

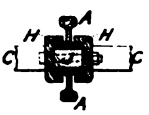


Fig. 21. ... Clamped B... Guide in ...

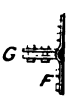
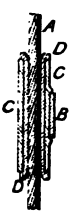
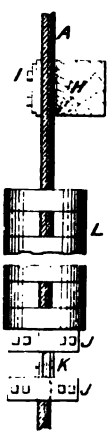


Fig. 19.—Section of Cage-shoe for Rope Guides.





... Feet to 1 Inch.

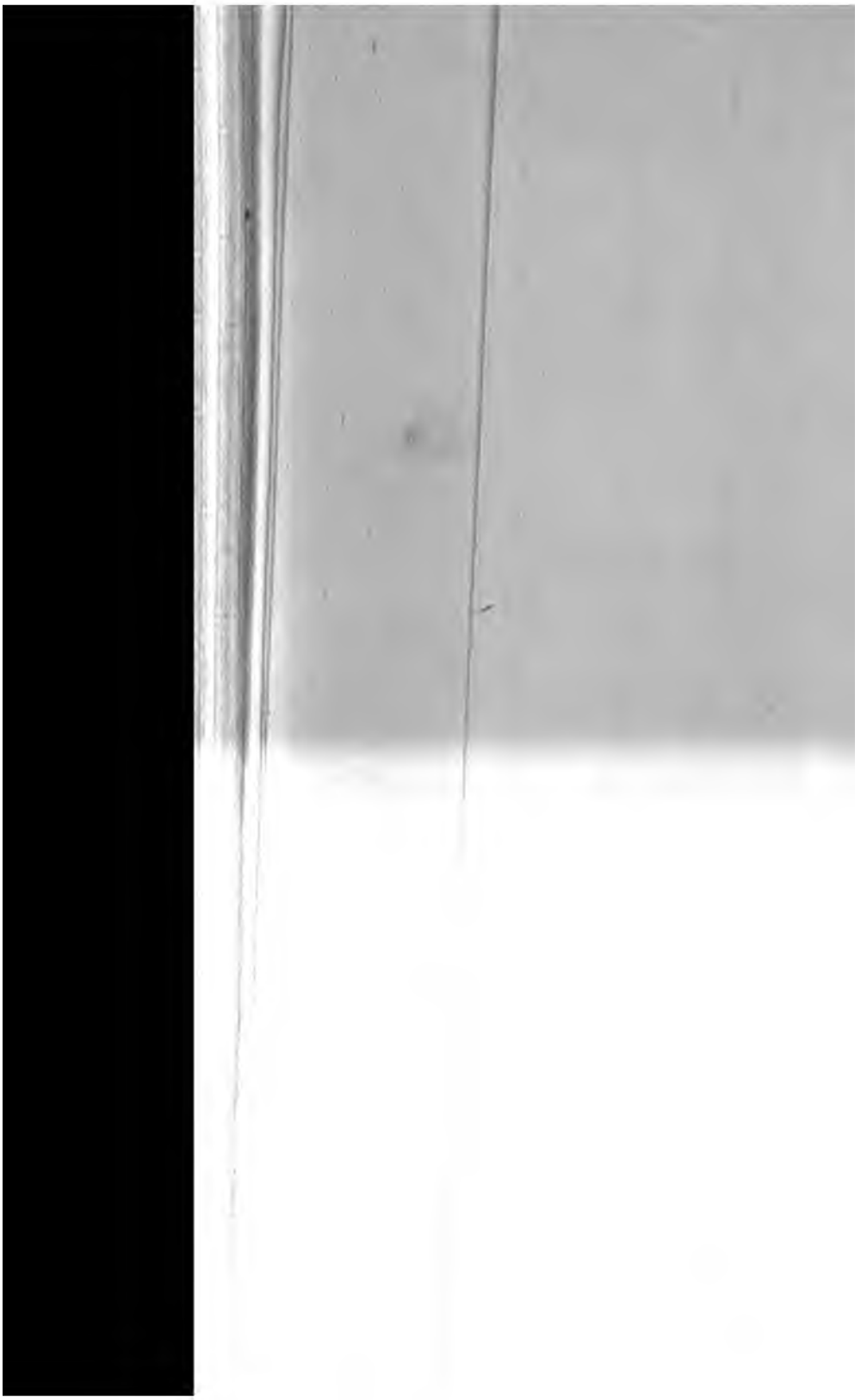
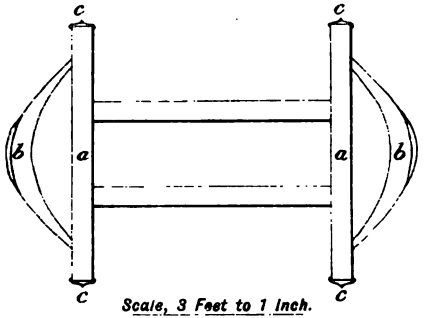


FIG. 1.—PLAN OF BANDS OR STRETCHER



Scale, 3 Feet to 1 Inch.

FIG. 2.—SIDE ELEVATION OF BOGIE, ETC.

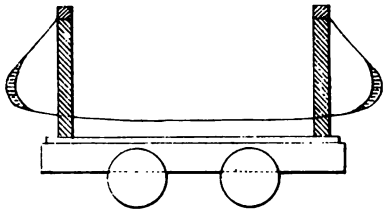
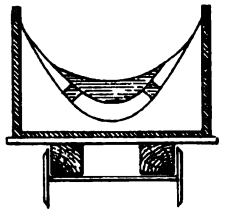


FIG. 3.—END ELEVATION OF BOGIE, ETC.



Scale, 3 Feet to 1 Inch.

FIG. 4.—SIDE ELEVATION OF CAP.

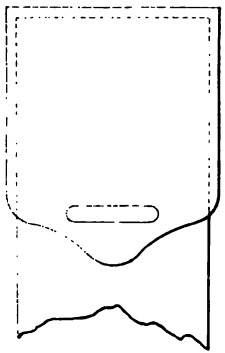


FIG. 5.—END ELEVATION OF CAP.

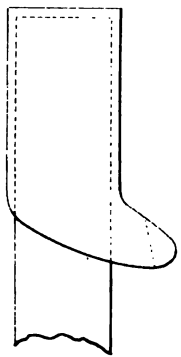


FIG. 6.—PLAN OF HOOK

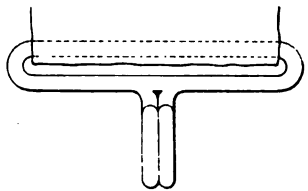
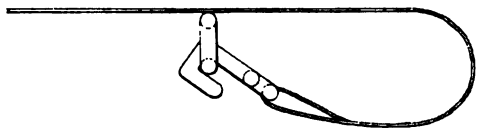


FIG. 7.—SIDE ELEVATION OF HOOK.

FIG. 8.—END ELEVATION OF EYE.

FIG. 9.—SIDE ELEVATION OF HOOK AND EYE.



Scale, 3 Inches to 1 Inch.

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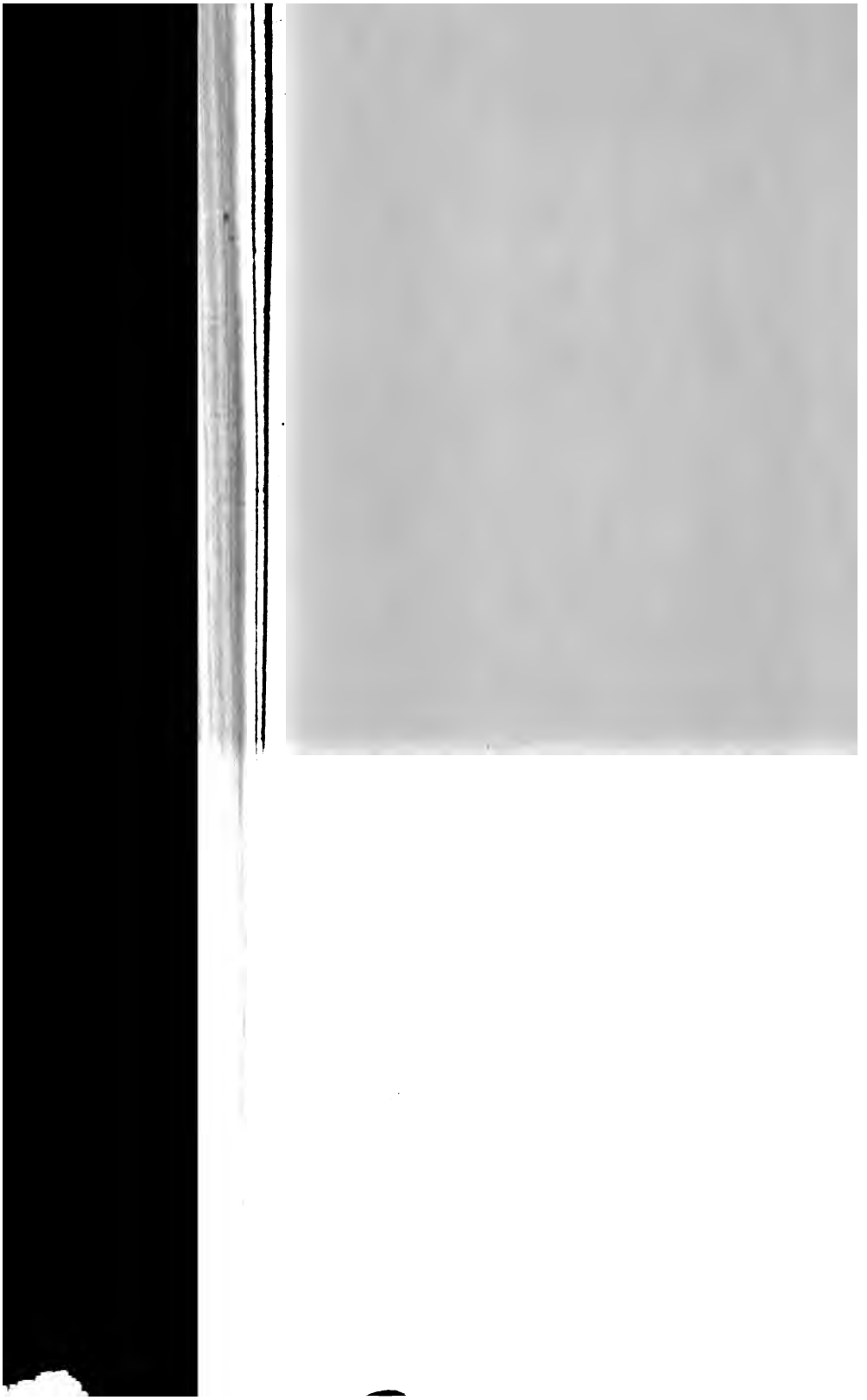


To illustrate Mr. A. Hanley's Paper on "The Hanley Cage Guardian."

FIG. 1.—SIDE ELEVATION.

FIG. 3.—SECTION SHOWING GRIP OF SHOE UPON A ROPE-GUIDE.

FIG. 4.—ELEVATION SHOWING ANGLE OF INCLINATION OF SHACKLES.

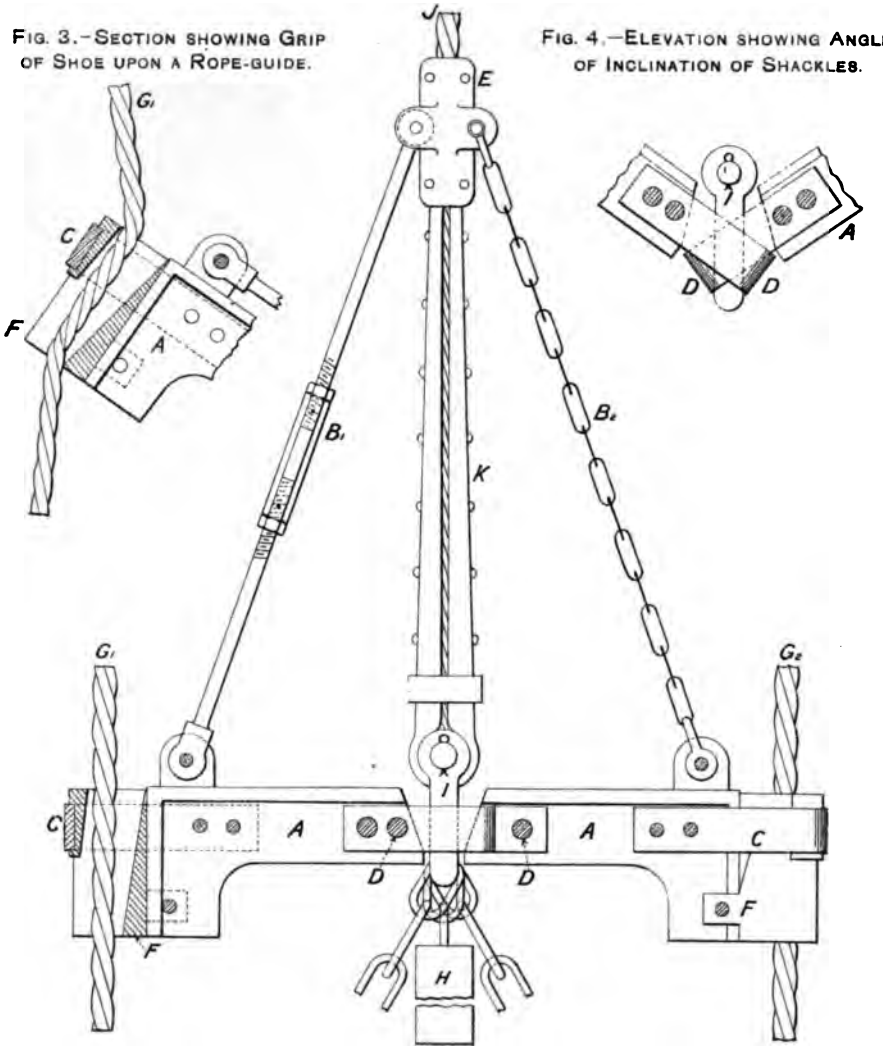
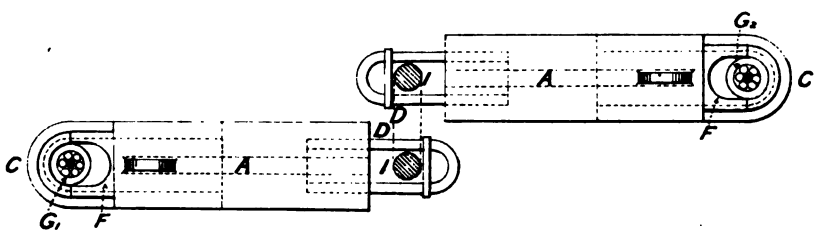


FIG. 2.—PLAN.



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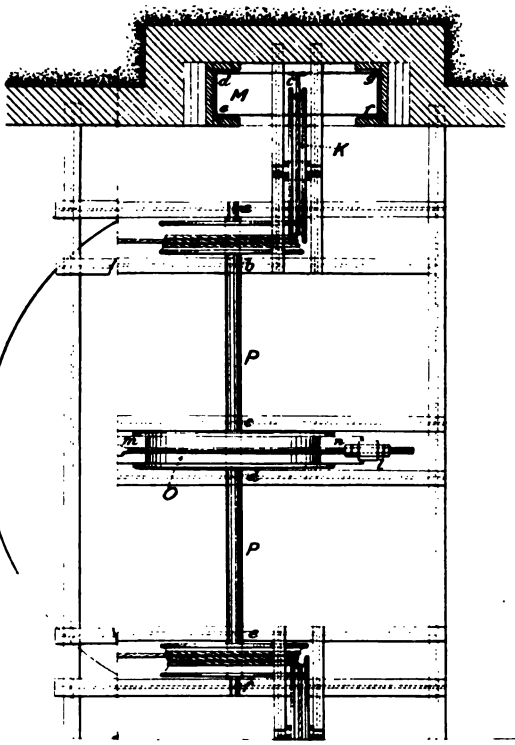

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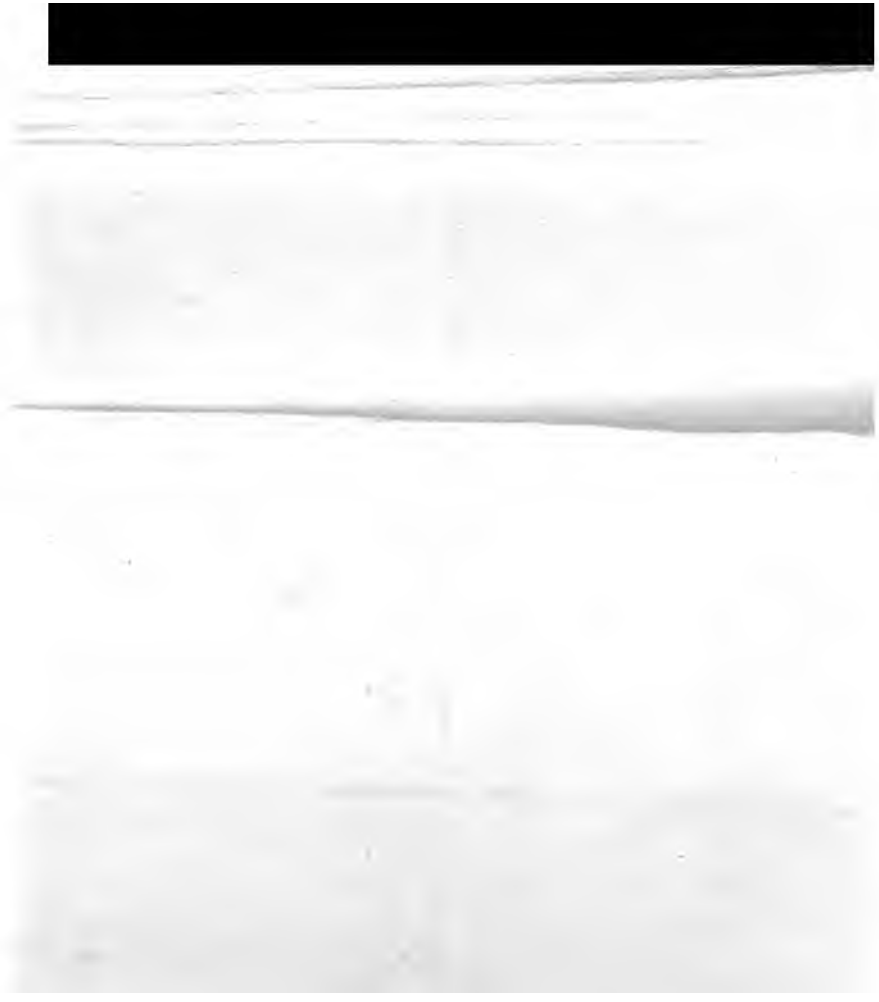

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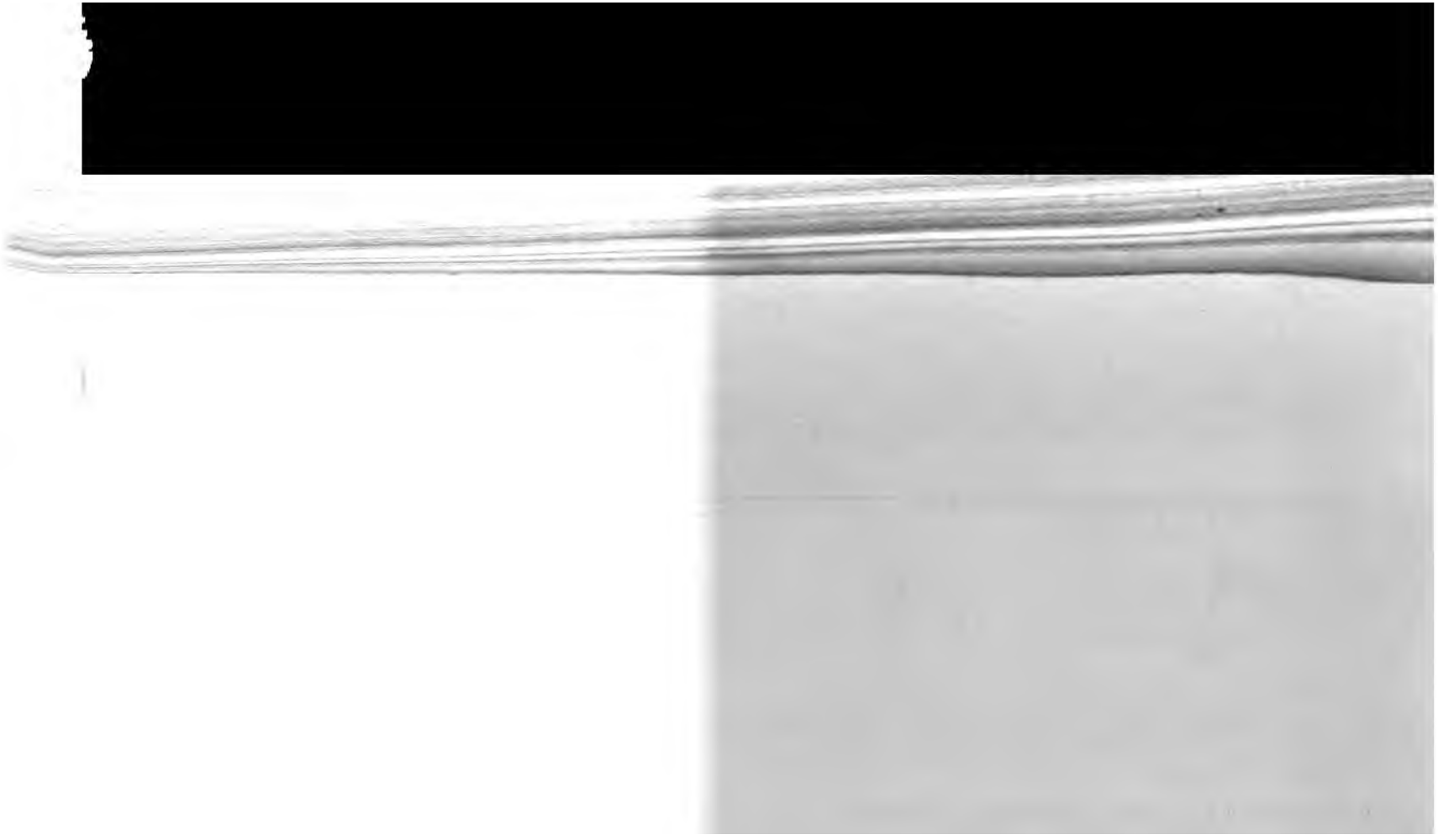
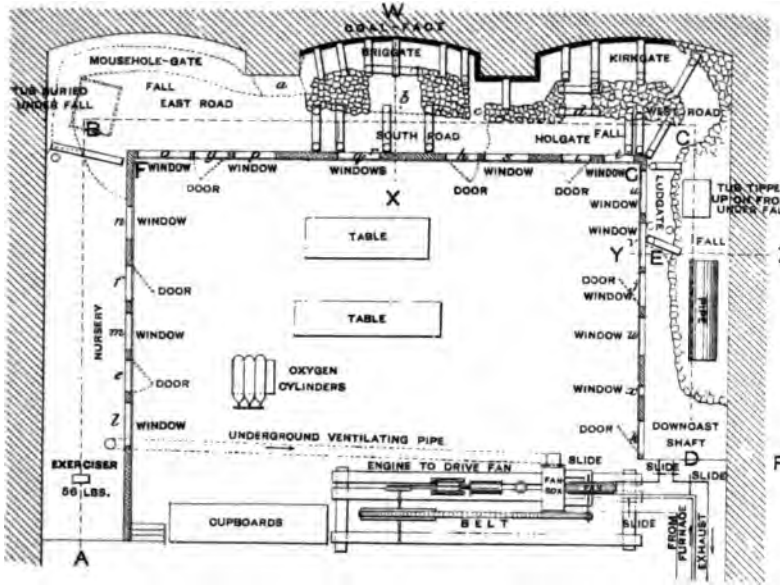


FIG. 1.—PLAN OF LOWER ROADWAYS.



Scale, 14 Feet to 1 Inch

FIG. 2.—PLAN OF UPPER ROADWAYS.

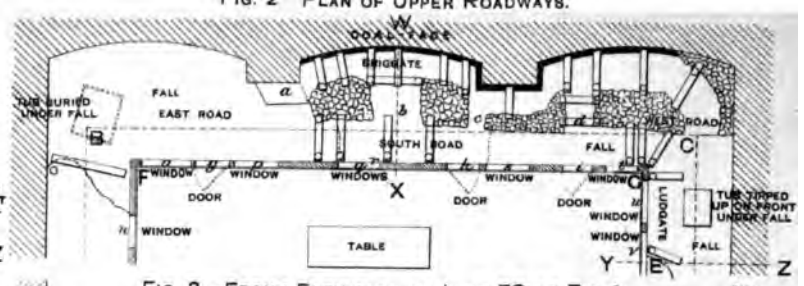


FIG. 3.—FRONT ELEVATION ON LINE FG OF FIG. 1.

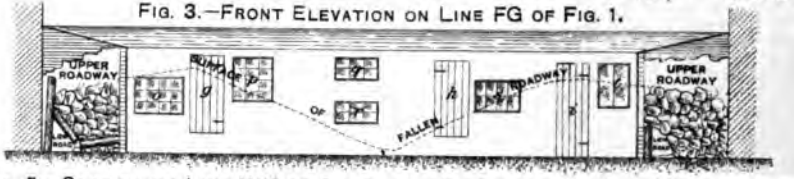


FIG. 5.—SECTION ON LINE WX OF FIG. 1.

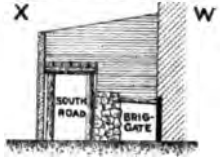
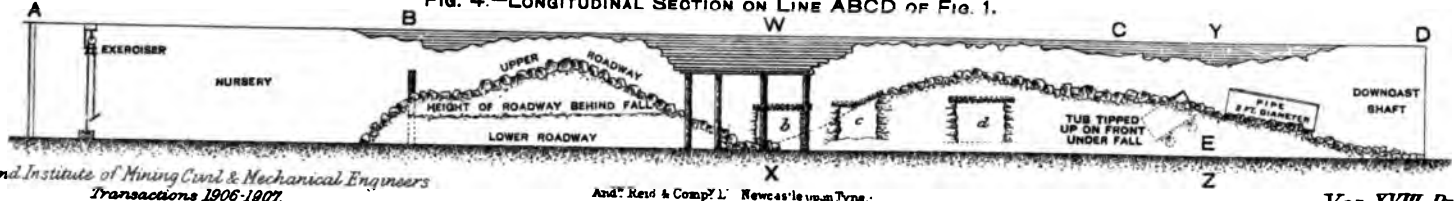


FIG. 6.—SECTION ON LINE YZ OF FIG. 1.

FIG. 4.—LONGITUDINAL SECTION ON LINE ABCD OF FIG. 1.



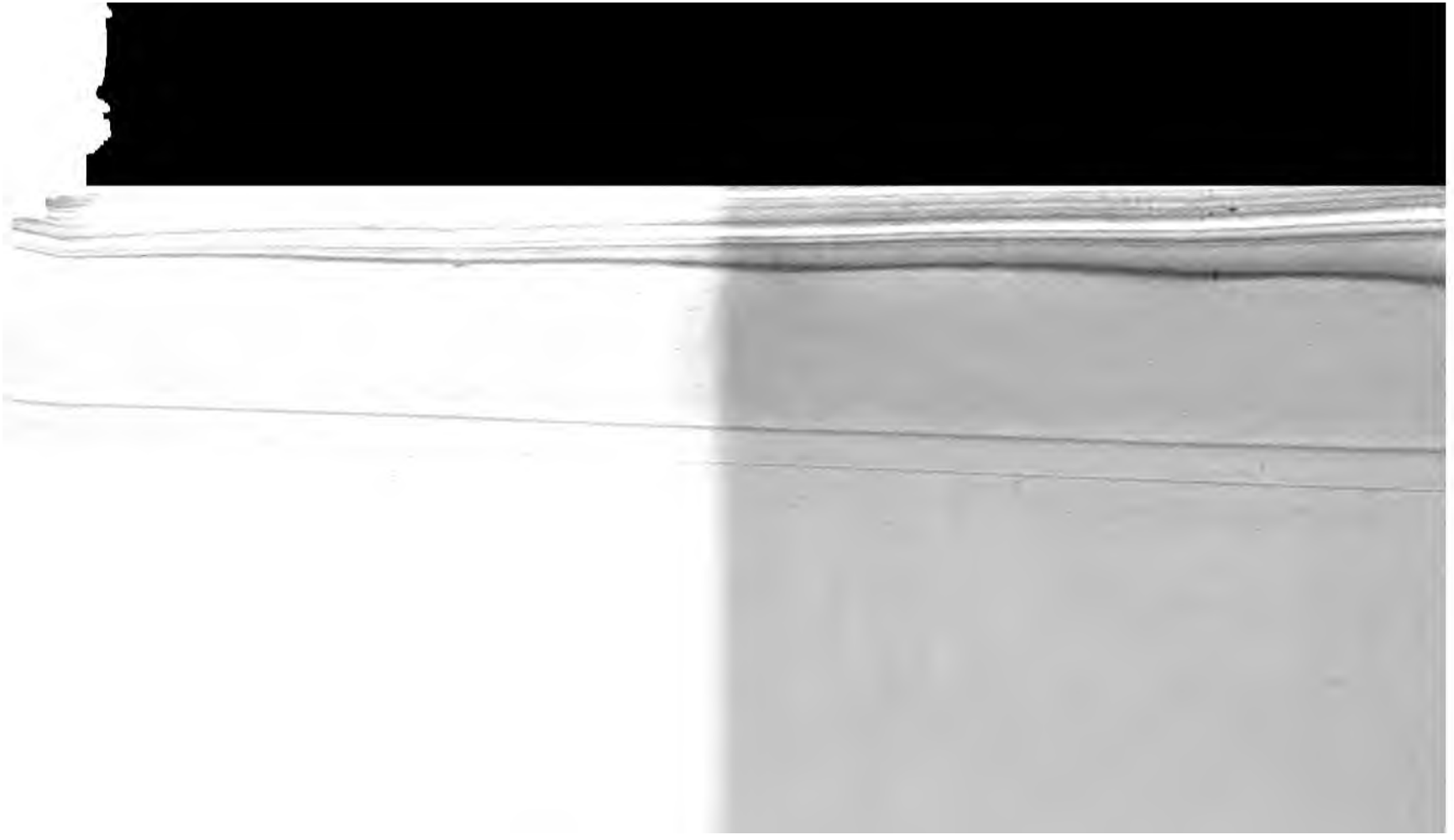
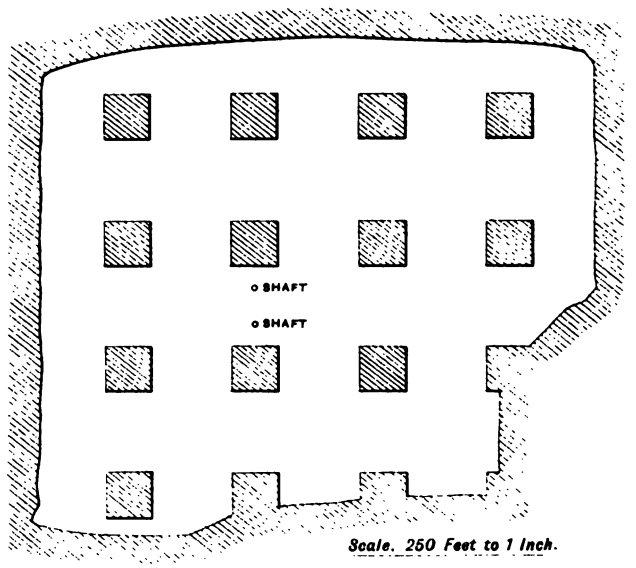
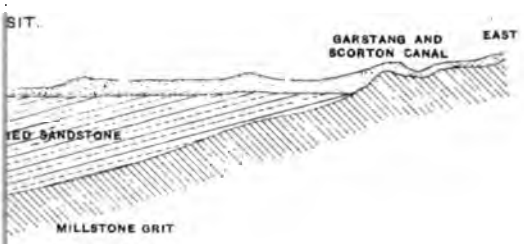


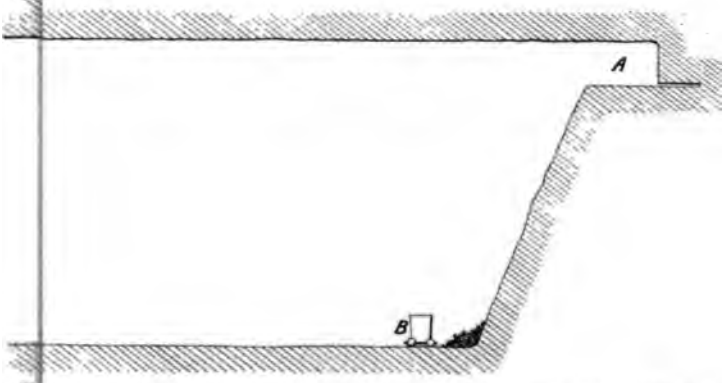
FIG. 4.—PLAN OF ROCK-SALT MINE.



Scale. 250 Feet to 1 Inch.



Miles to 1 Inch.



VOL. XXX, PLATE IV.

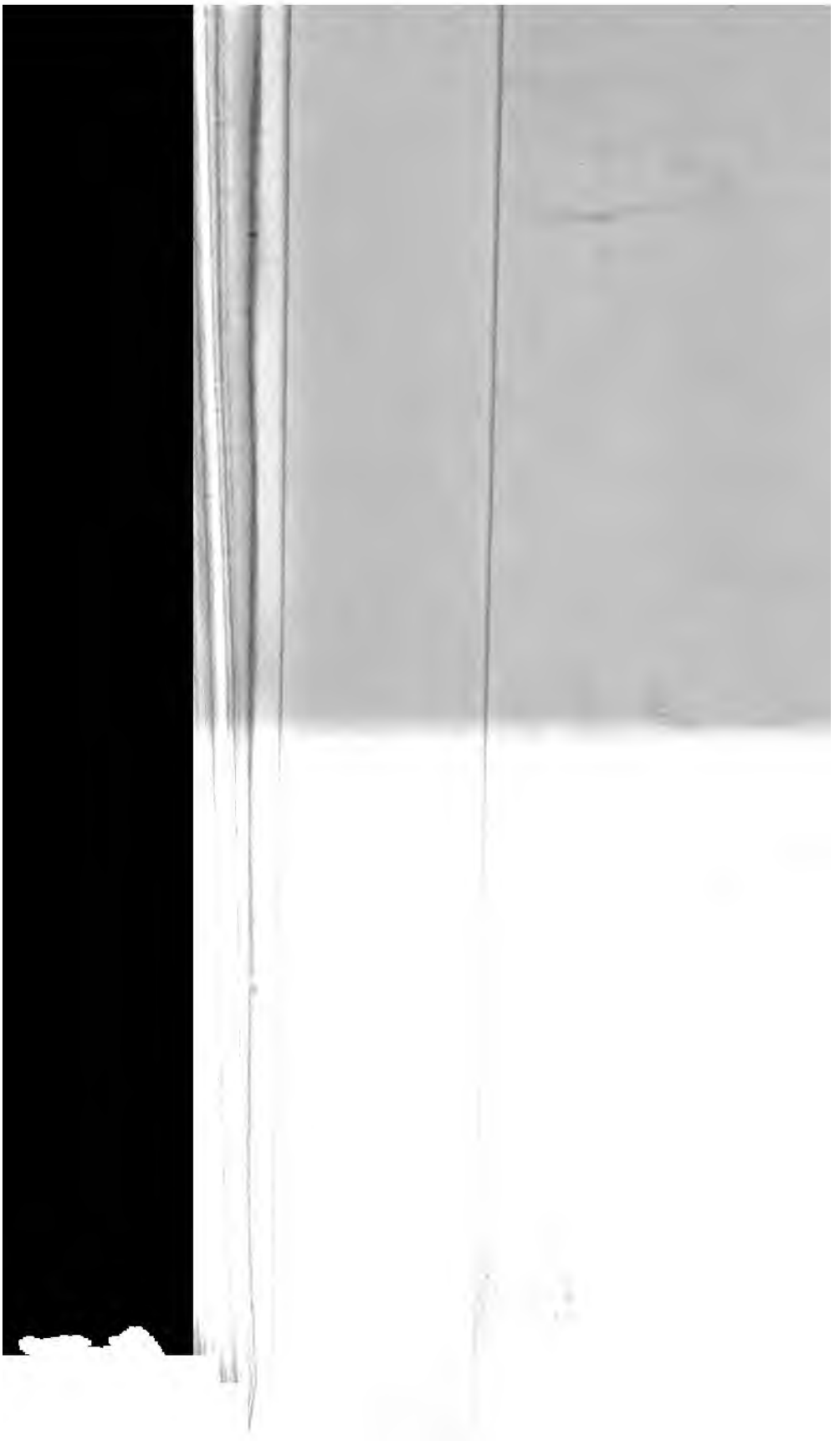


FIG. 4.—PLAN OF HEADING, AC, FIG. 1.

FIG. 5.—SECTION ON LINE WX, FIG. 4.

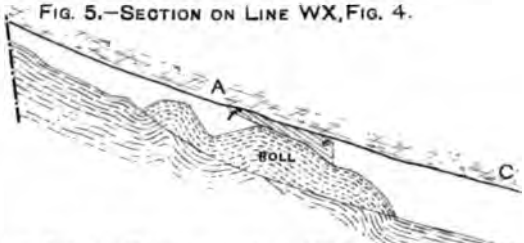
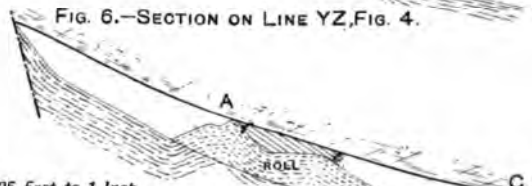
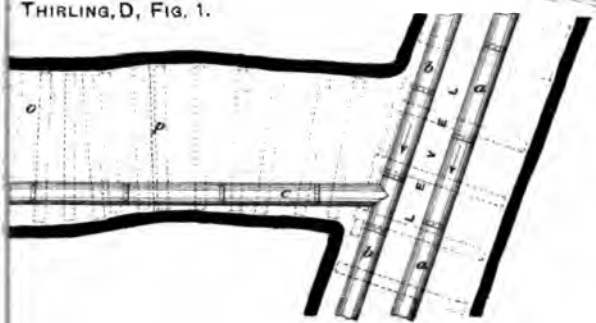


FIG. 6.—SECTION ON LINE YZ, FIG. 4.



Scale, 25 Feet to 1 Inch.

THIRLING, D, FIG. 1.



OF THIRLING, D, FIG. 1.

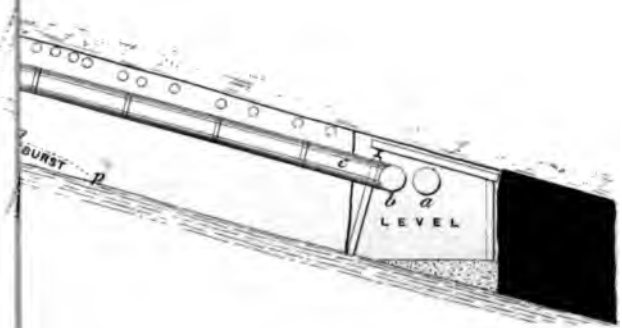


FIG. 2.
CROSS SECTION OF OVEN ON LINE YZ OF FIG. 1.

FIG. 3.
CROSS SECTION OF OVEN ON LINE WX OF FIG. 1.

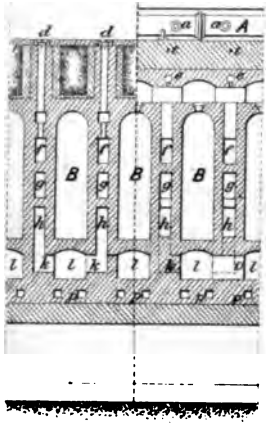
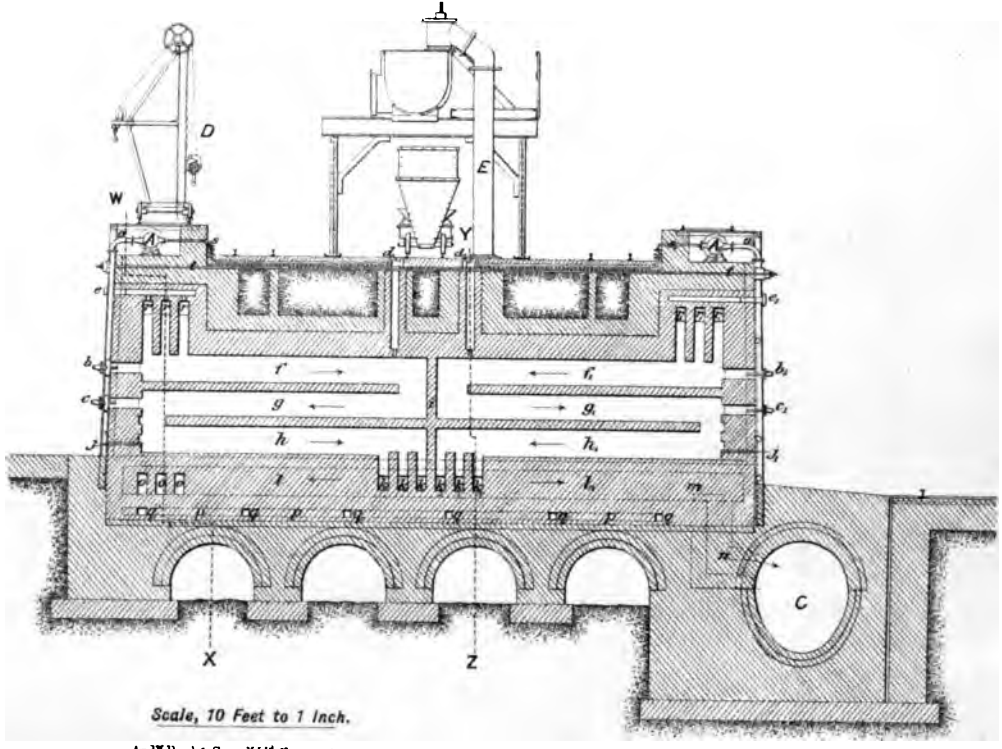


FIG. 1.– LONGITUDINAL SECTION THROUGH THE RIGHT-HAND WALL OF AN OVEN.



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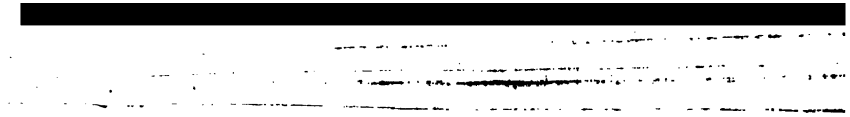


KOPPERS WASTE HEAT HEATING FLUES.

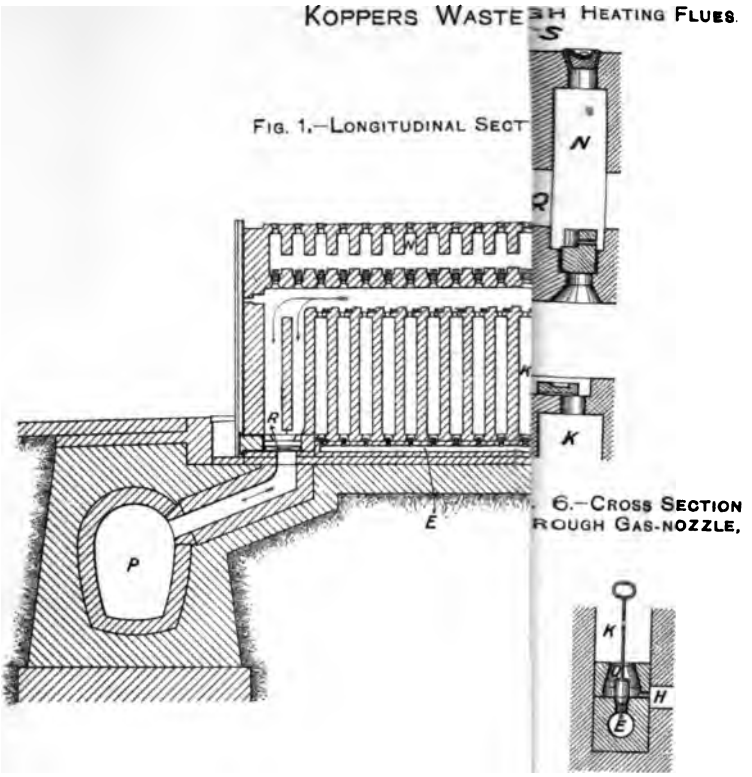
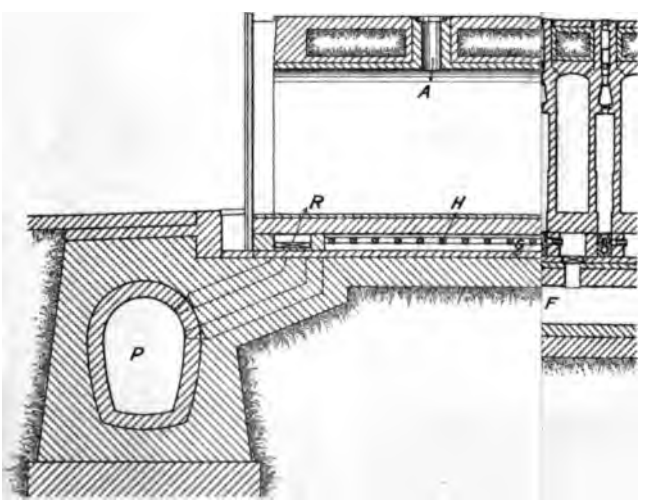


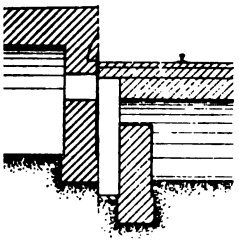
FIG. 1.—LONGITUDINAL SECT

6.—CROSS SECTION
ROUGH GAS-NOZZLE.

FIG. 2.—LONGITUDINAL SECTION THROUGH OVENS.

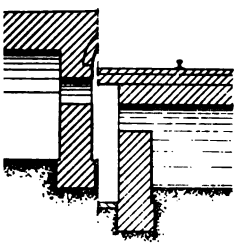


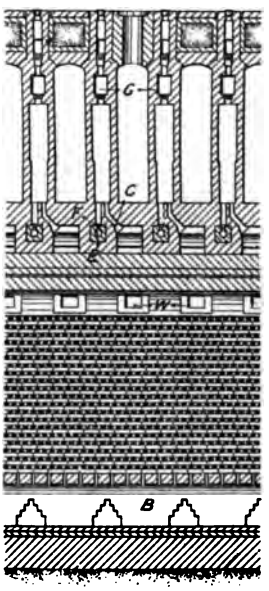
OVEN :

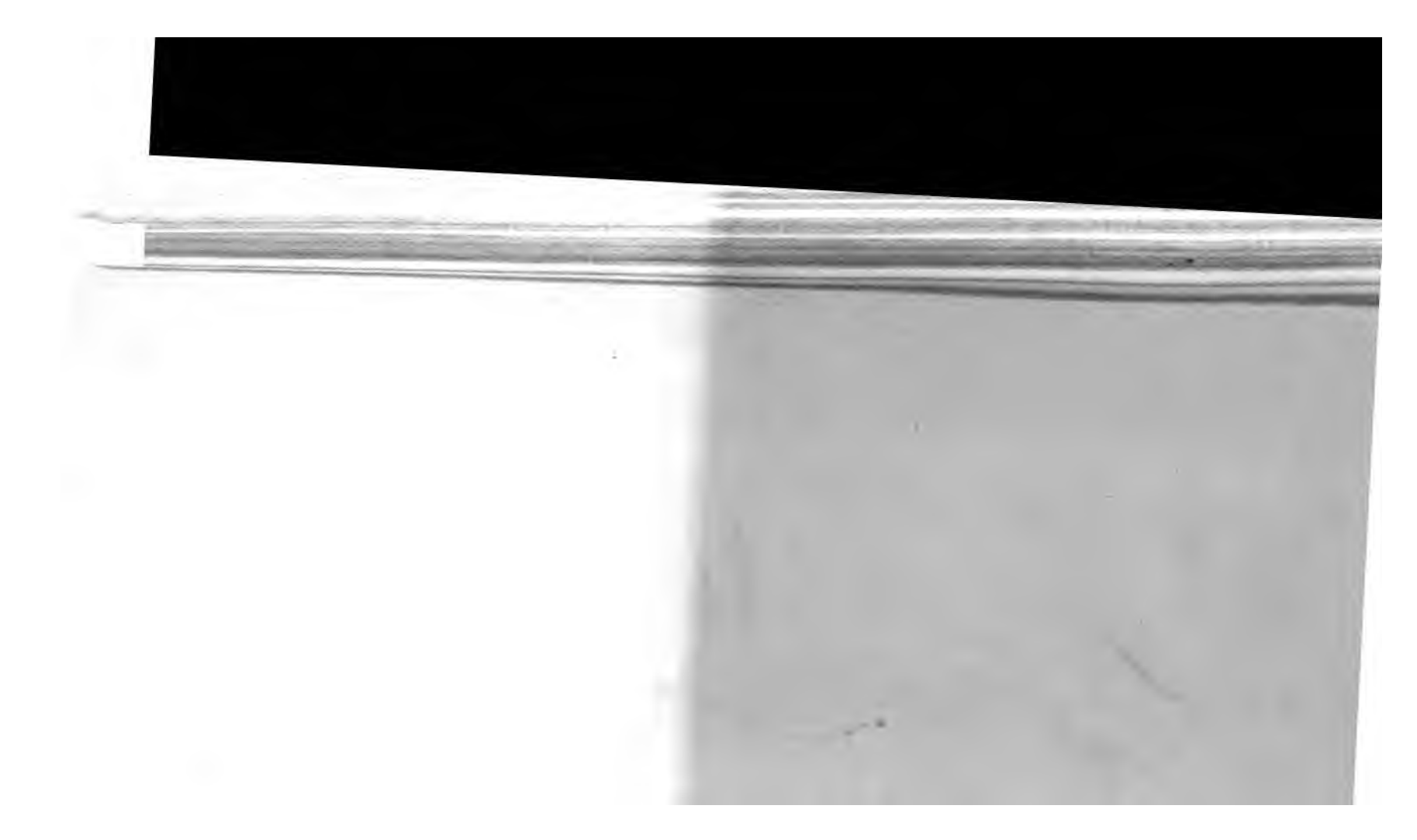


Scale, 10 Feet to 1 Inch.

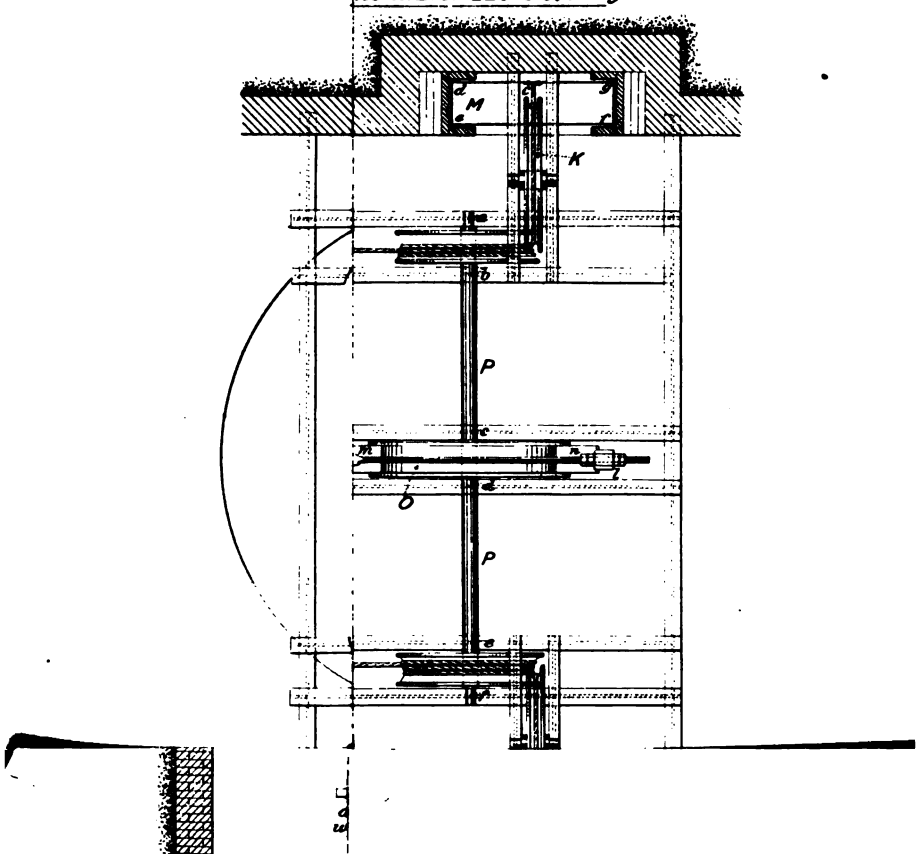
FIG. 9.--CROSS SECTION THROUGH OVENS.







Ides at New Moss Colliery."



Scale, 6 Feet to 1 Inch.

JOHN DAGLISH.

PRESIDENT OF THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS, 1884-1886.

Born on June 26th, 1828, and died on August 9th, 1906.

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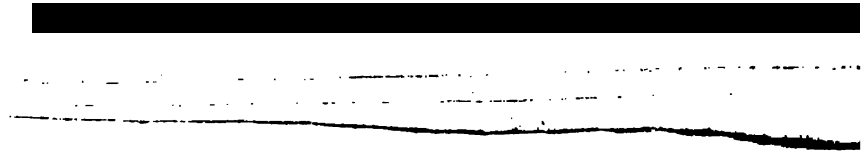
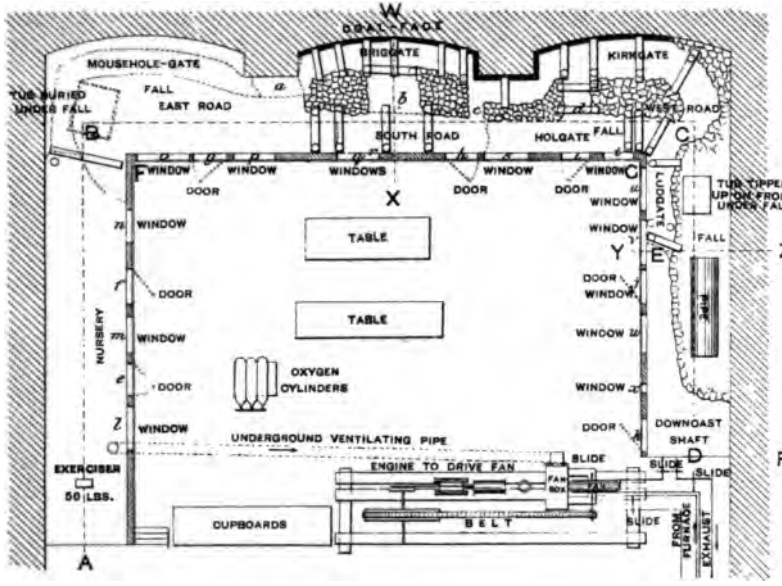


To illustrate a Description of the "Experimental Gallery at Altofts Collieries."

FIG. 1.—PLAN OF LOWER ROADWAYS.



Scale, 14 Feet to 1 Inch

FIG. 2.—PLAN OF UPPER ROADWAYS.

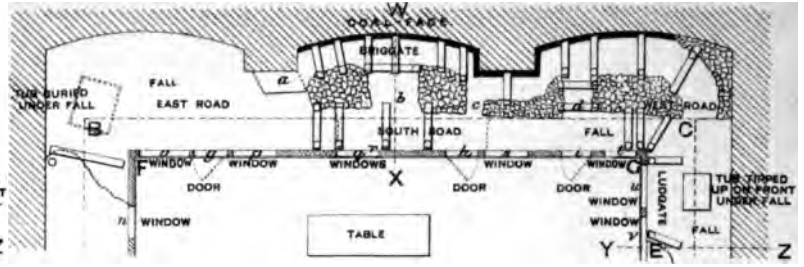


FIG. 3.—FRONT ELEVATION ON LINE FG OF FIG. 1.

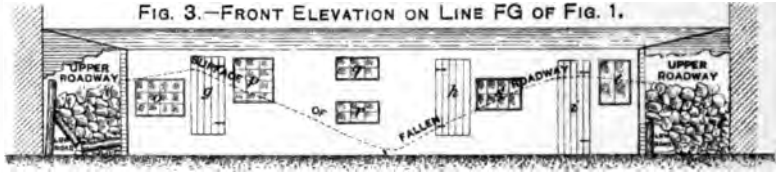


FIG. 5.—SECTION ON LINE WX OF FIG. 1.

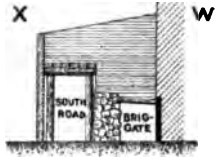
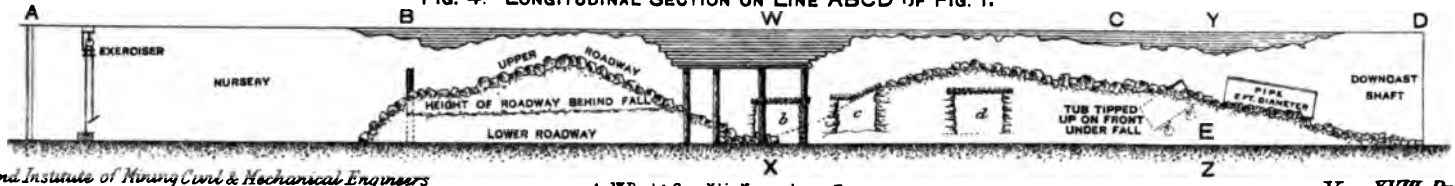


FIG. 6.—SECTION ON LINE YZ OF FIG. 1.

FIG. 4.—LONGITUDINAL SECTION ON LINE ABCD OF FIG. 1.



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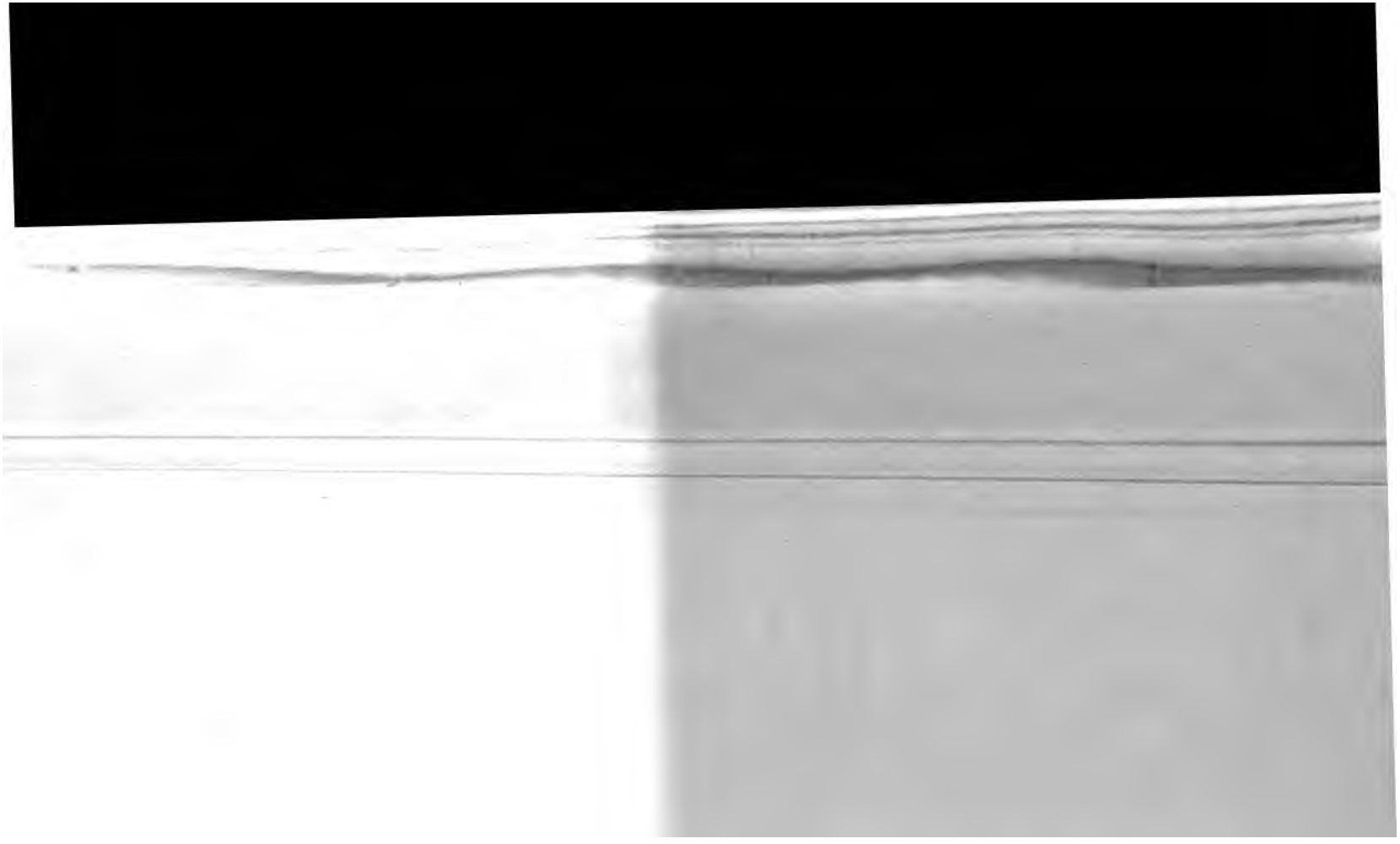
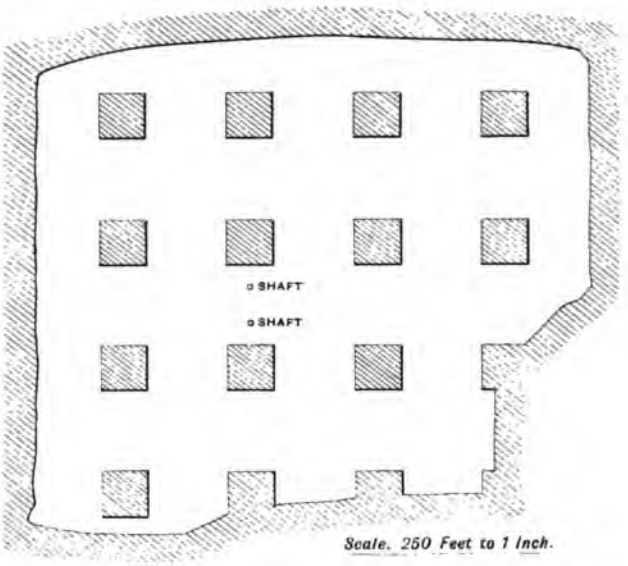
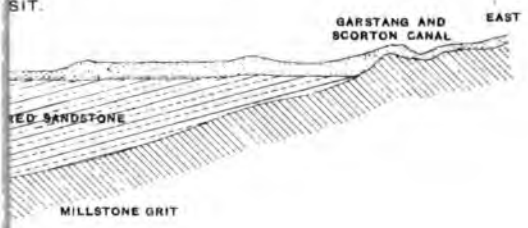


FIG. 4.—PLAN OF ROCK-SALT MINE.

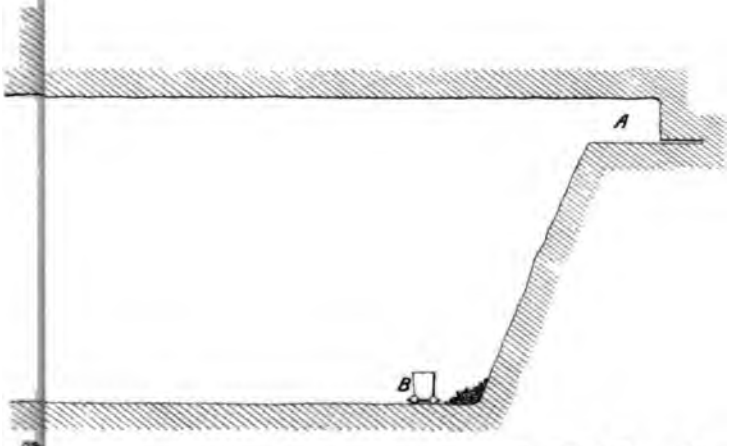


Scale. 250 Feet to 1 Inch.

SIT.



Miles to 1 Inch.



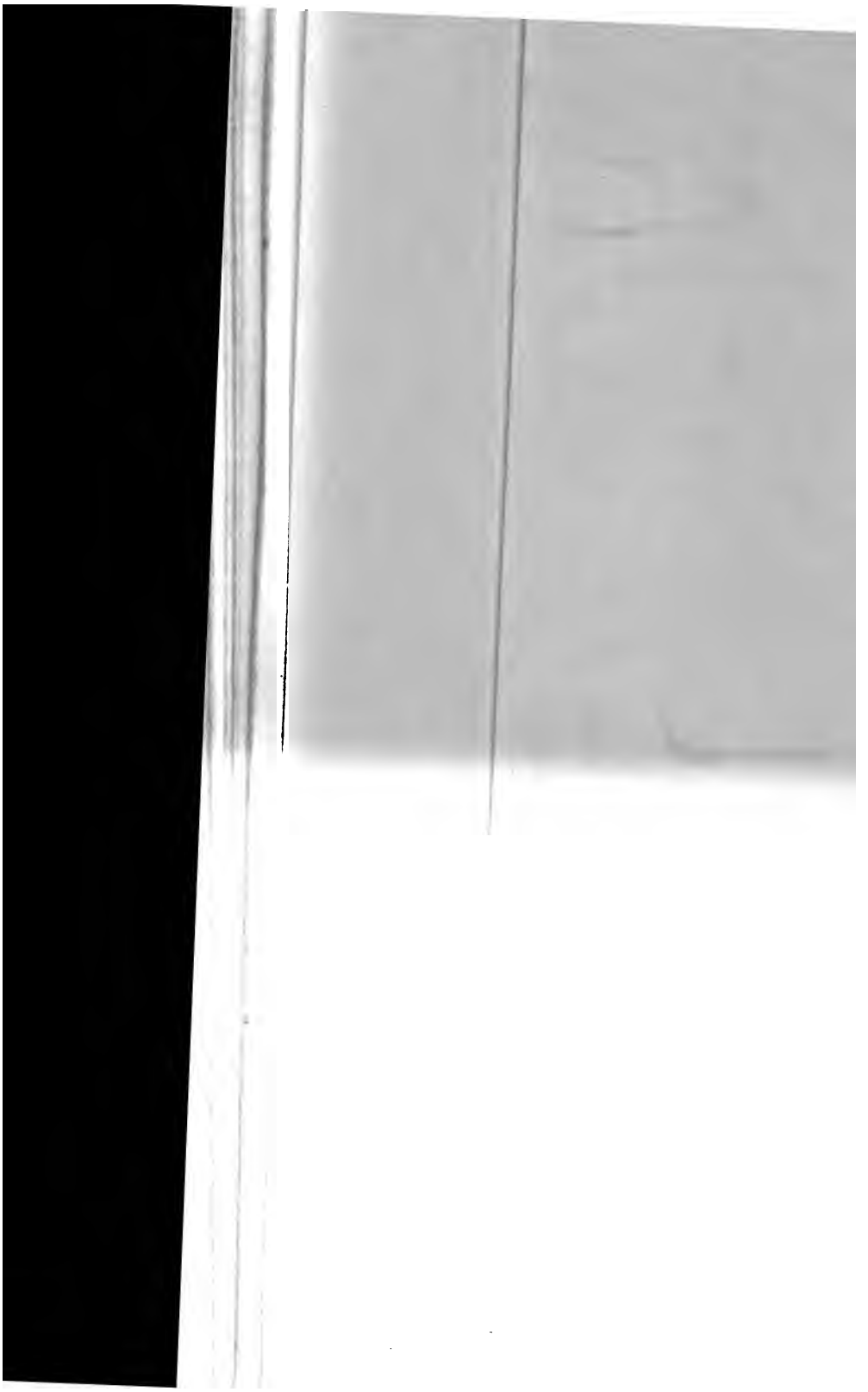


FIG. 4.—PLAN OF HEADING, AC, FIG. 1.

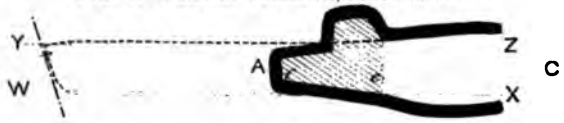


FIG. 5.—SECTION ON LINE WX, FIG. 4.

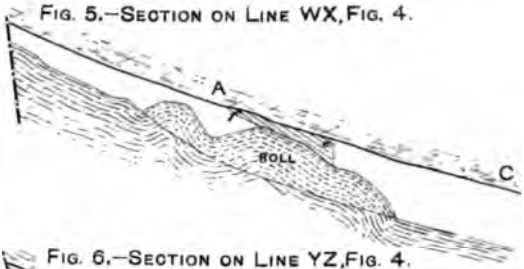
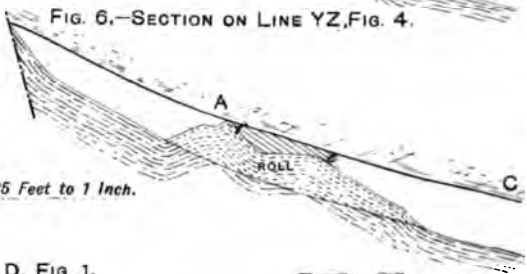
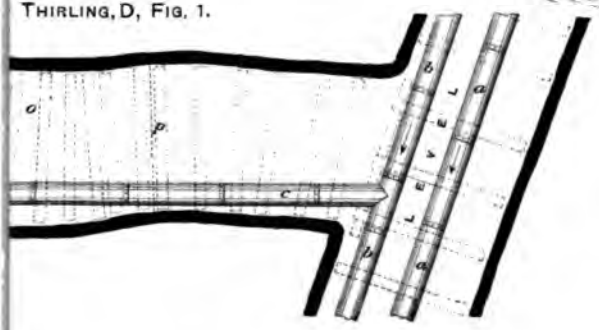


FIG. 6.—SECTION ON LINE YZ, FIG. 4.

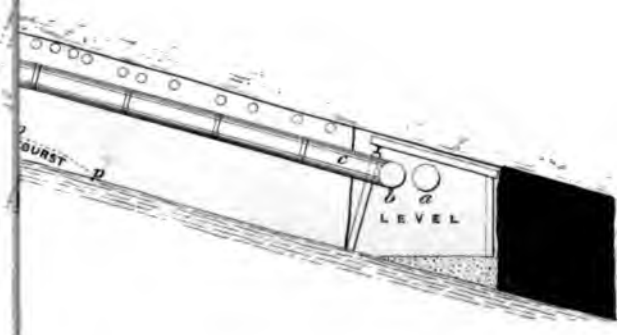


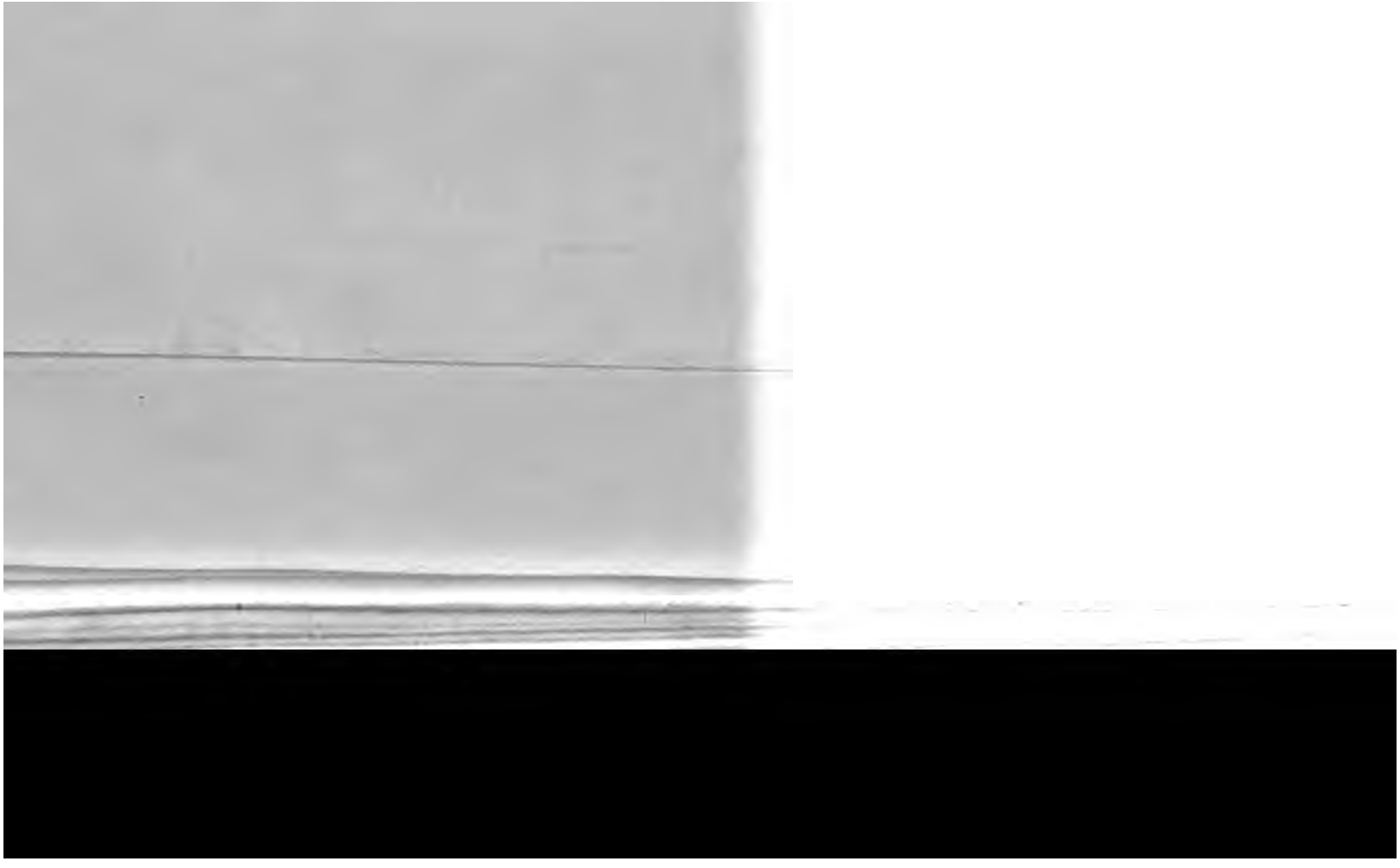
Scale, 25 Feet to 1 Inch.

THIRLING, D, FIG. 1.



OF THIRLING, D, FIG. 1.





To illustrate Mr. W. B. M. Jackson's Paper on "A Bye-product Coking plant."

FIG. 2.
CROSS SECTION OF OVEN ON LINE YZ OF FIG. 1.

FIG. 3.
CROSS SECTION OF OVEN ON LINE WX OF FIG. 1.

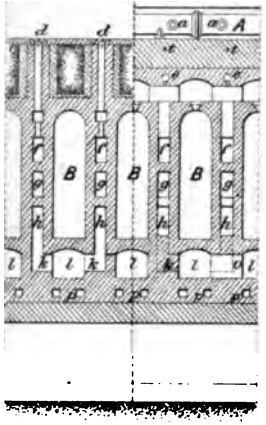
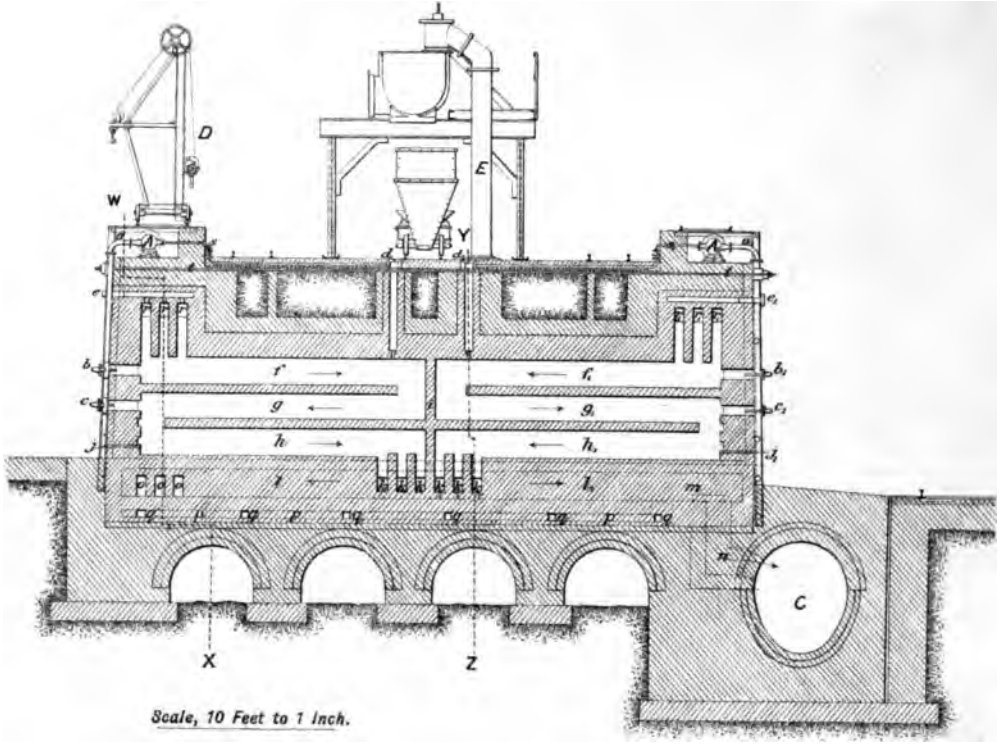


FIG. 1.– LONGITUDINAL SECTION THROUGH THE RIGHT-HAND WALL OF AN OVEN.



Scale, 10 Feet to 1 Inch.

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To illustrate Mr W. B. M. Jackson's Paper on "A Bye-product Coking plant."

FIG. 2.
CROSS SECTION OF OVEN ON LINE YZ OF FIG. 1.

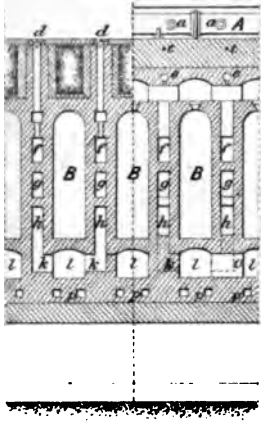
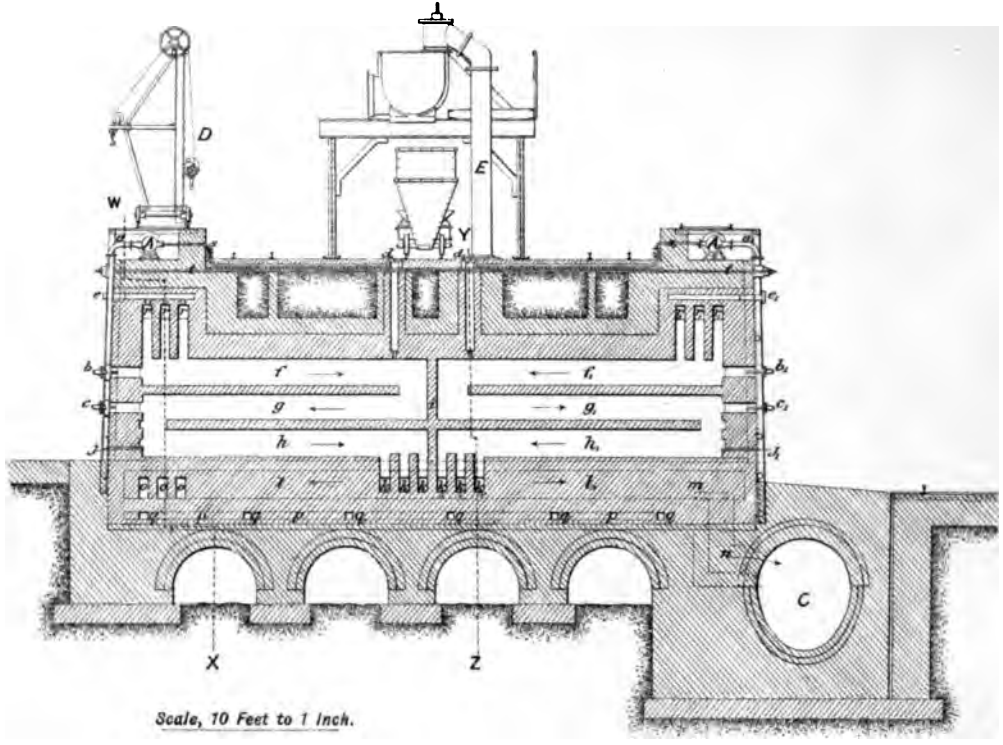


FIG. 3.
CROSS SECTION OF OVEN ON LINE WX OF FIG. 1.

FIG. 1.– LONGITUDINAL SECTION THROUGH THE RIGHT-HAND WALL OF AN OVEN.



Scale, 10 Feet to 1 Inch.

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KOPPERS WASTE-HEAT HEATING FLUES.

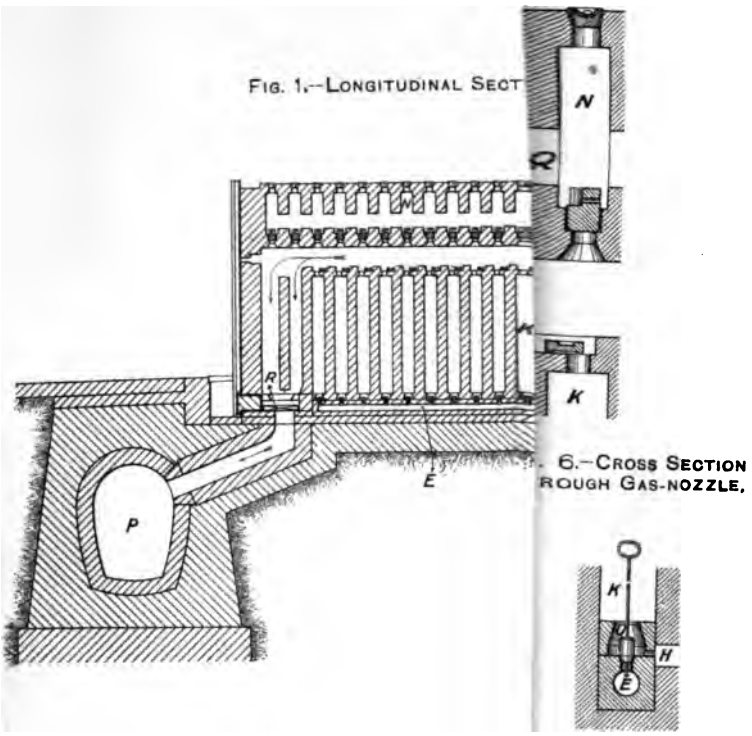
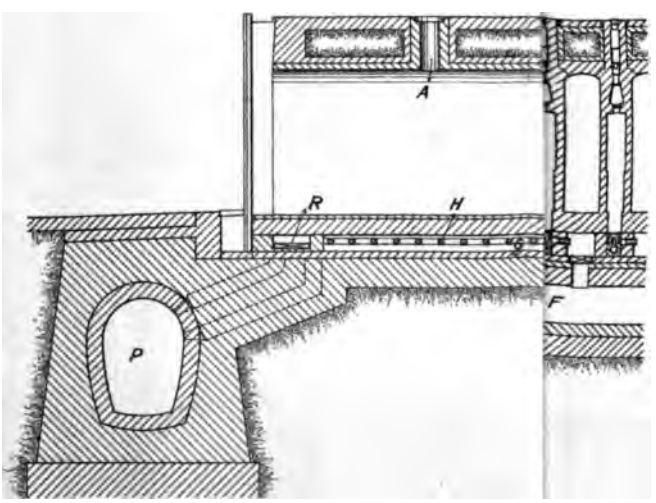


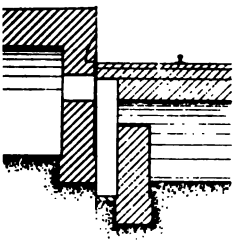
FIG. 1.—LONGITUDINAL SECT

FIG. 6.—CROSS SECTION ROUGH GAS-NOZZLE.

FIG. 2.—LONGITUDINAL SECTION THROUGH OVENS.

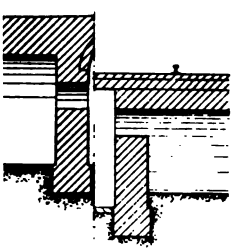


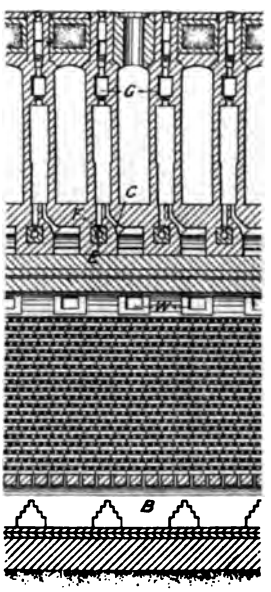
...OVEN:



Scale, 10 Feet to 1 Inch.

FIG. 9.--CROSS SECTION THROUGH OVENS.





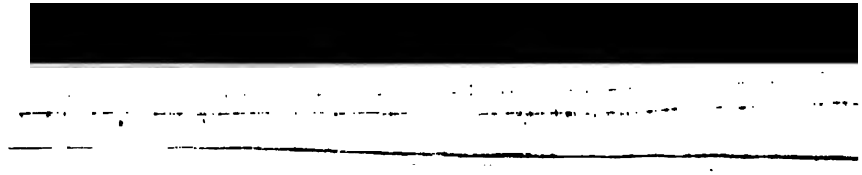
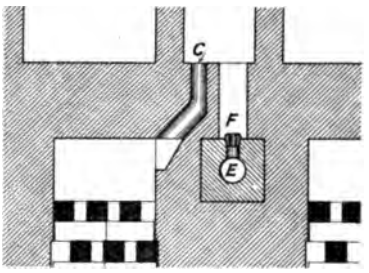
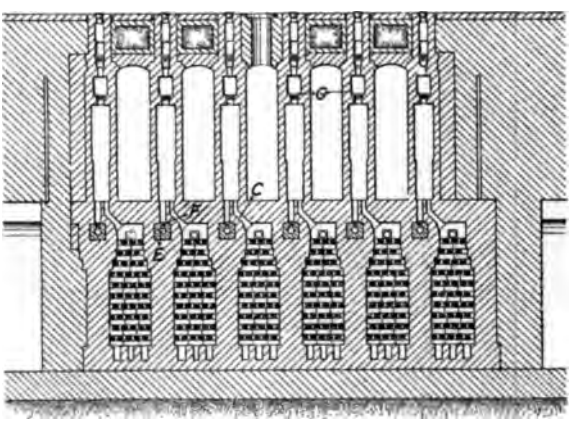


Fig. 13.—Cross Section through Gas-nozzle.

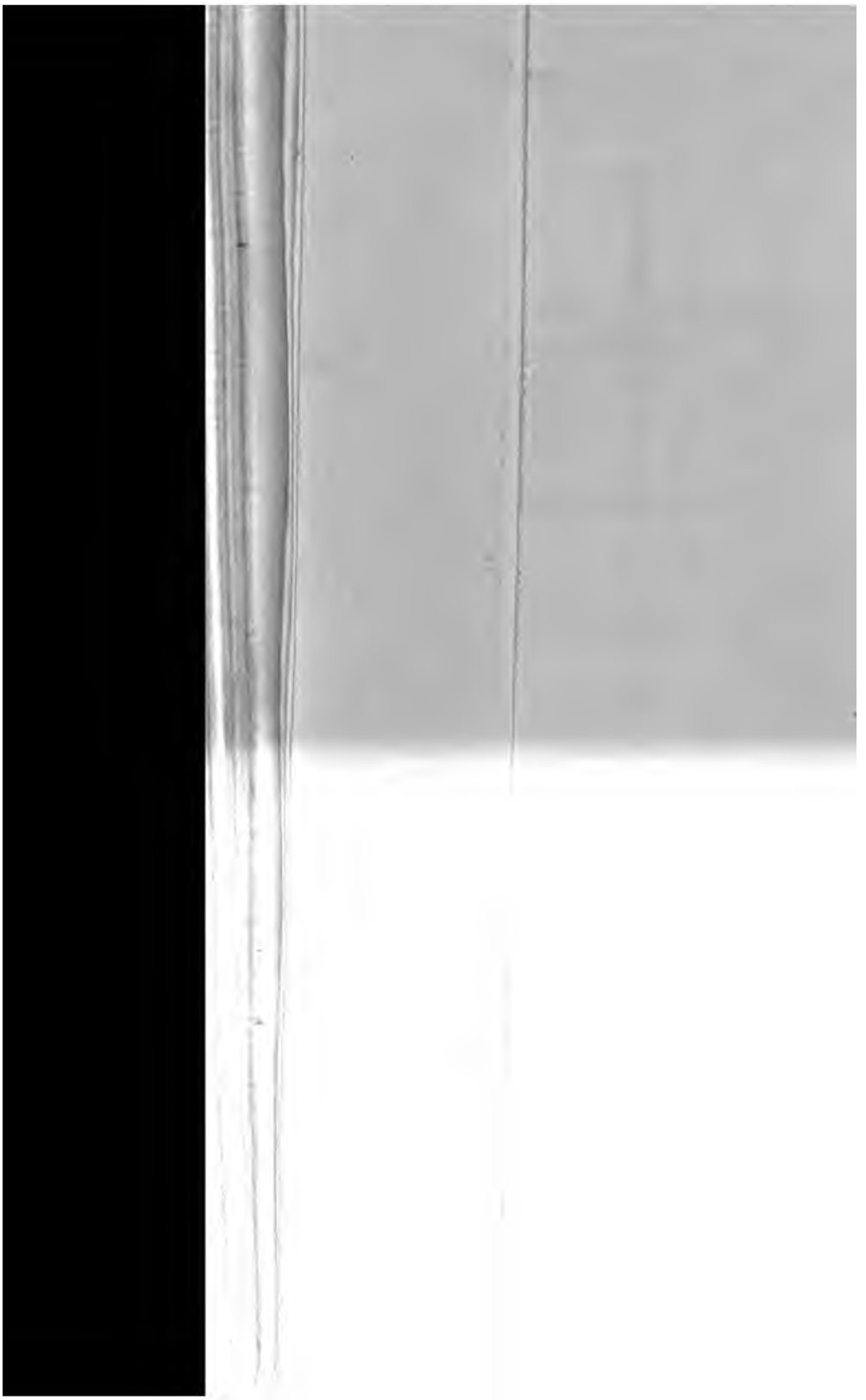


Scale, 2½ Feet to 1 Inch.

Fig. 12.—Cross Section through Ovens.



Feet to 1 Inch.



-OVEN :
NGEMENTS.

FIG. 15.—END ELEVATION OF FITTINGS.

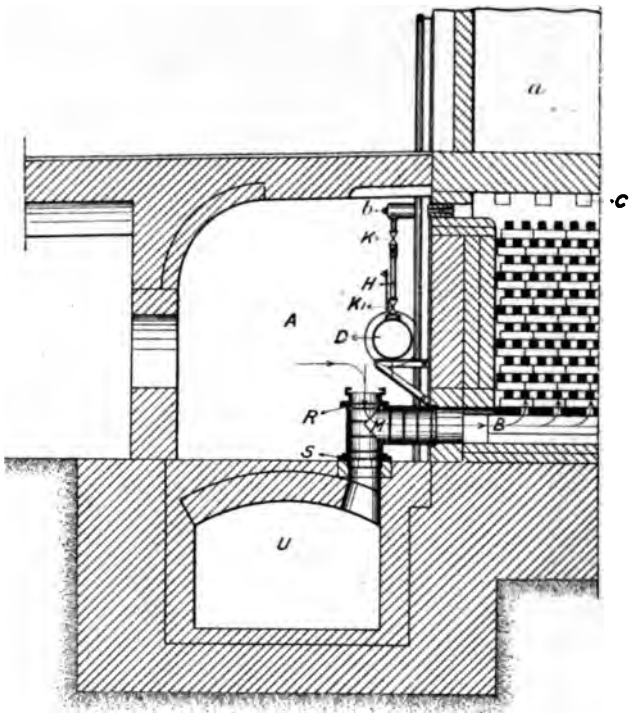
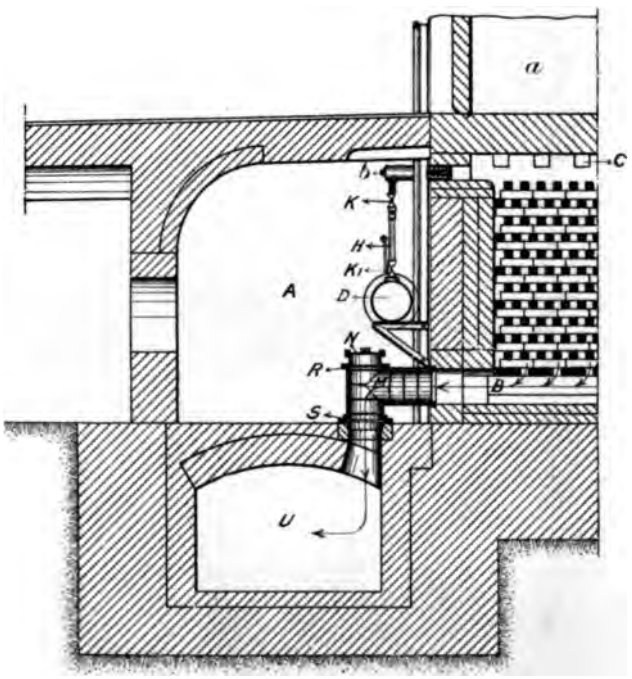
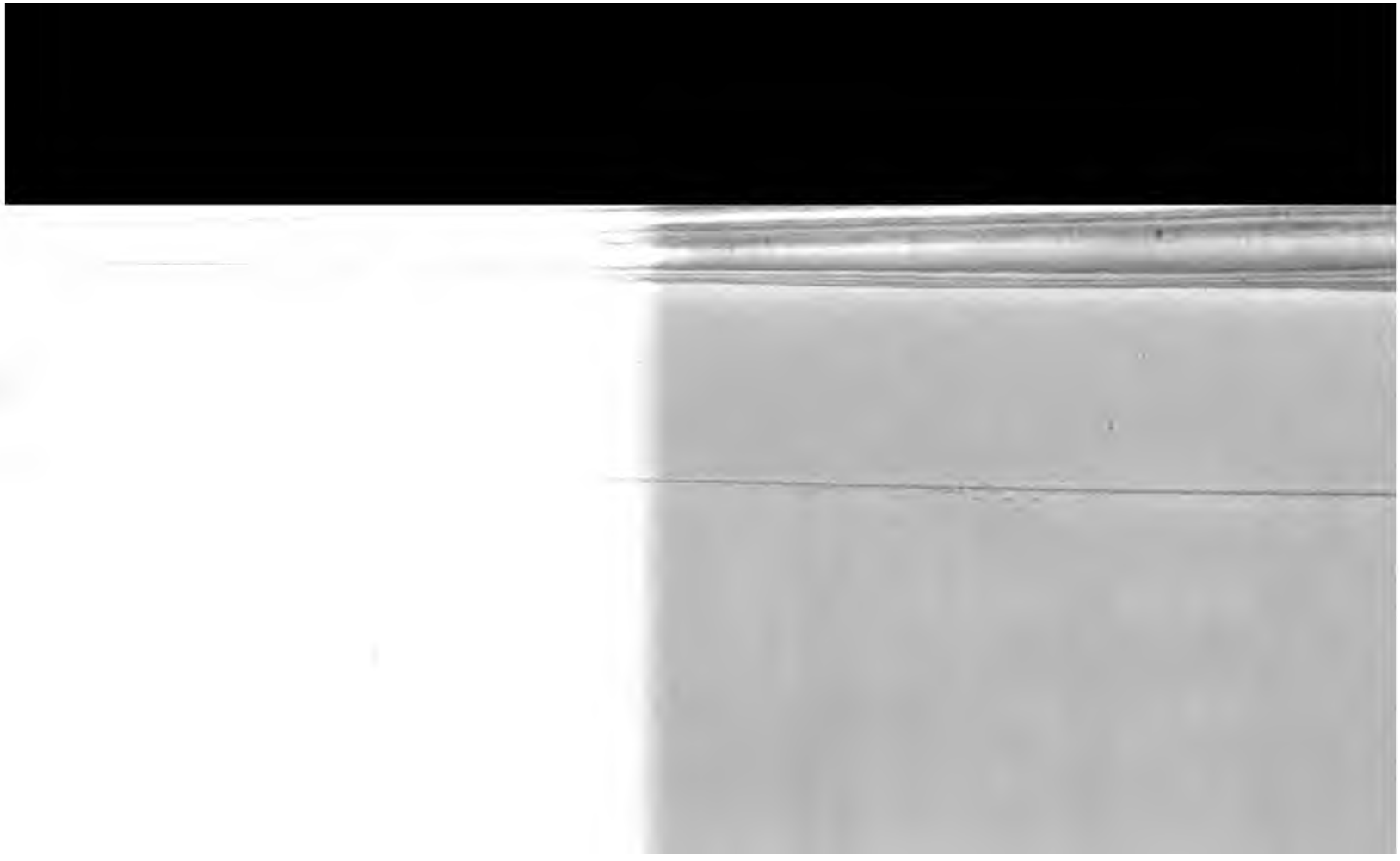


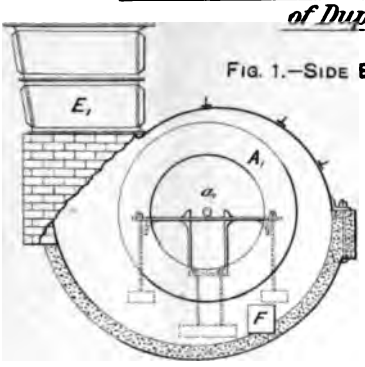
FIG. 17.—END ELEVATION OF FITTINGS.





To illustrate the Rev. C.M. Capell's Paper on "The Application of Duplicate Fans to Mines".

FIG. 1.—SIDE ELEVATION OF SINGLE-INLET FAN.



REFERENCE.

DIRECTION OF AIR-CURRENTS →

FIG. 2.—PLAN OF ARRANGEMENT OF DUPLICATE FANS WITH SINGLE-INLETS.

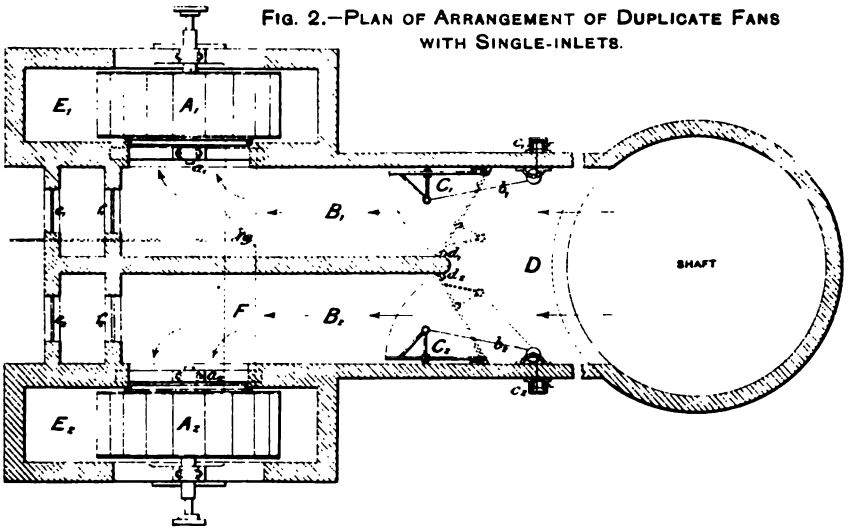
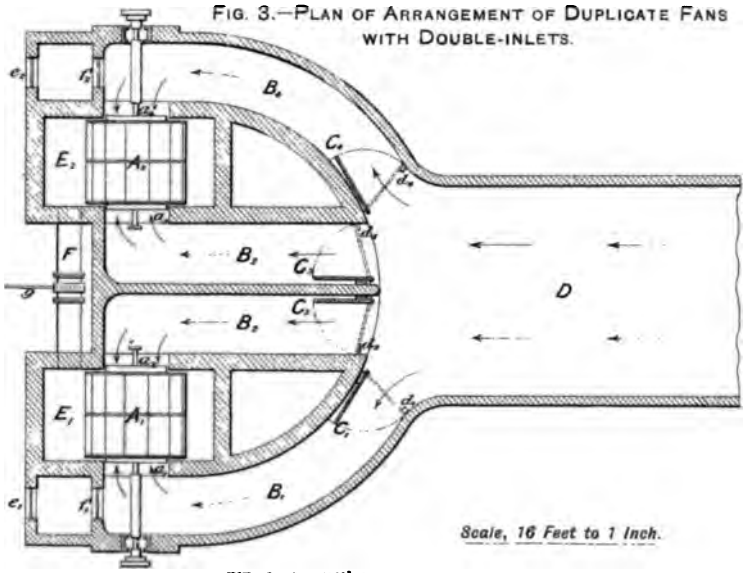


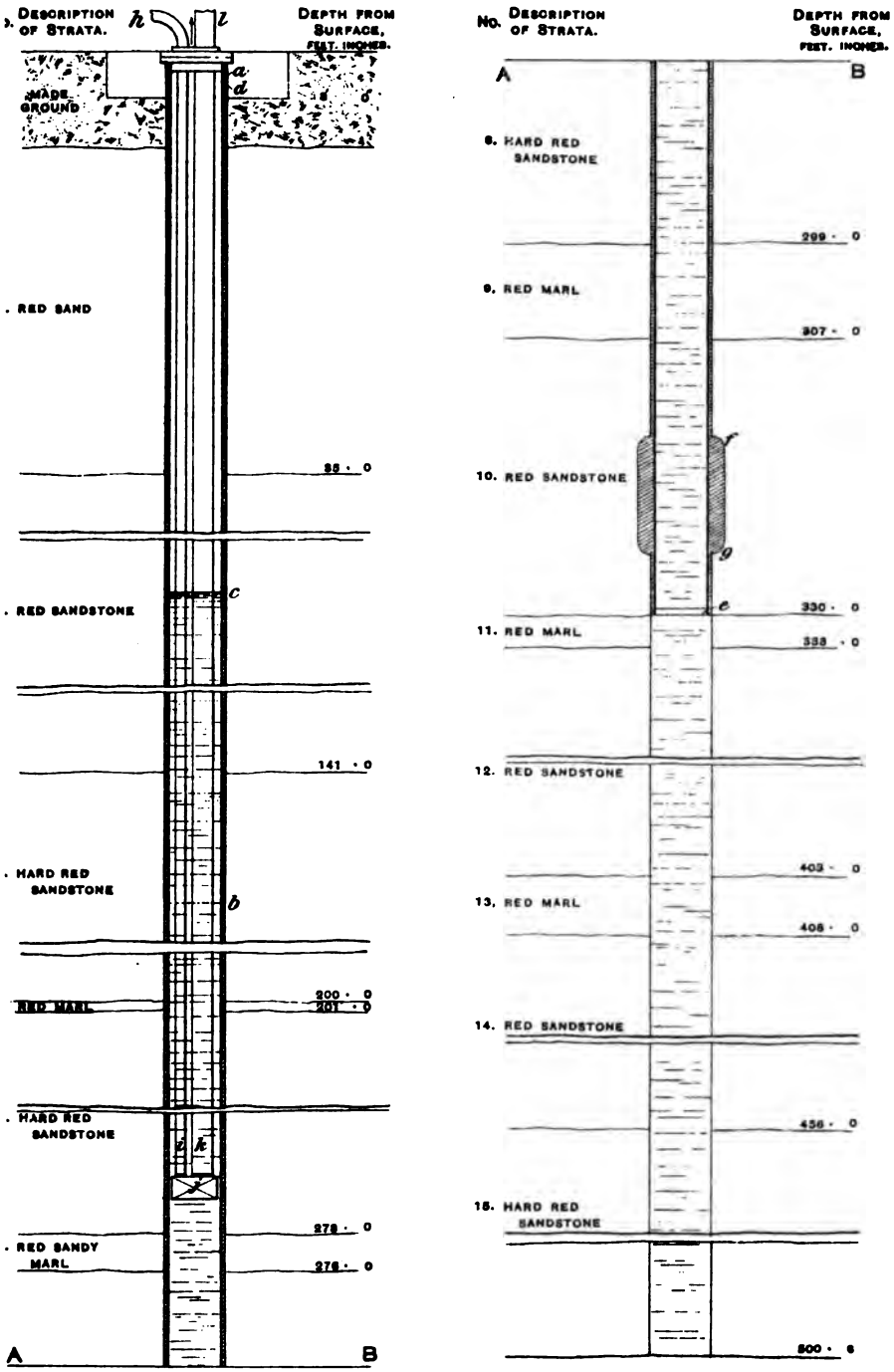
FIG. 3.—PLAN OF ARRANGEMENT OF DUPLICATE FANS WITH DOUBLE-INLETS.



And.w Reid & Comp.y L.td Newcastle upon Tyne

To illustrate Mr. H. F. Broadhurst's Paper on "Water-supplies," etc.

FIG. 1.—SECTION OF BORE-HOLE AND AIR-LIFT PUMP AT MONUMENT LANE, BIRMINGHAM.



Horizontal Scale, 4 Feet to 1 Inch. *Vertical Scale, 16 Feet to 1 Inch.*

REFERENCES.
TUBES
CEMENT

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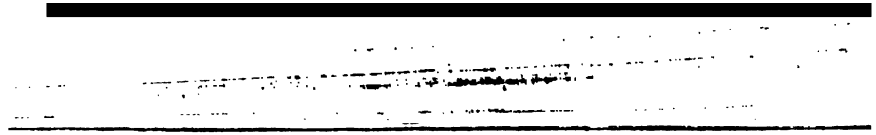
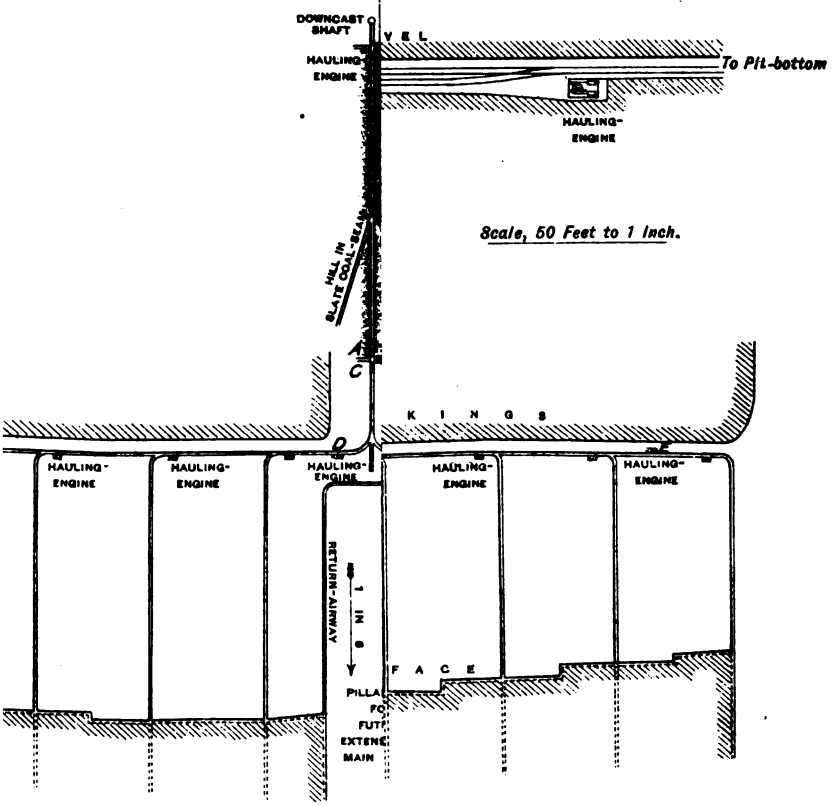
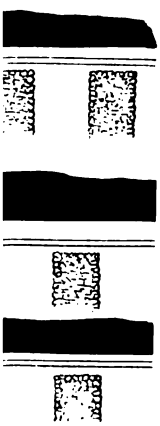
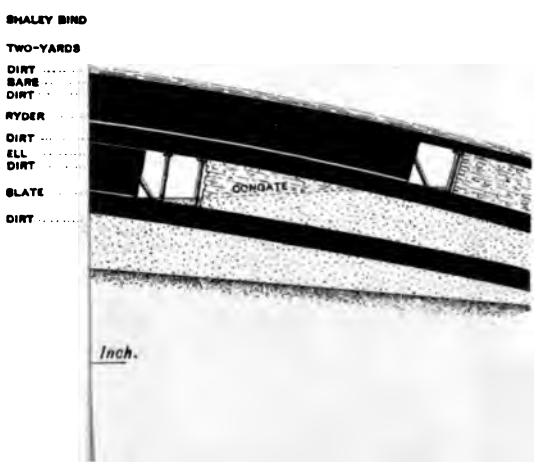


8.—Plan of Workings in Two Yard[illegible]ng Hauling-engine on Level Clara Pit, Griff Colliery. | Top of Hill.

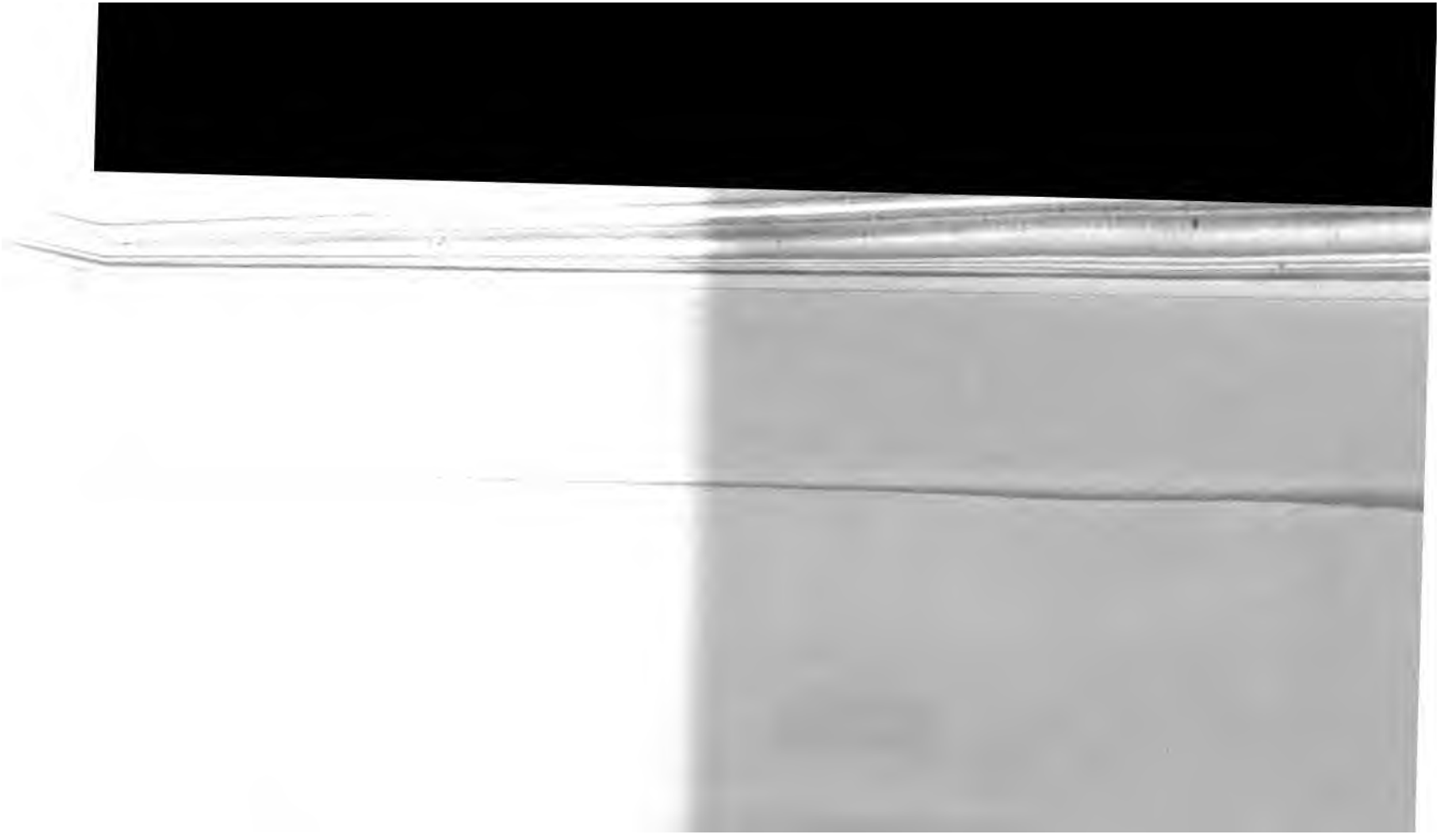




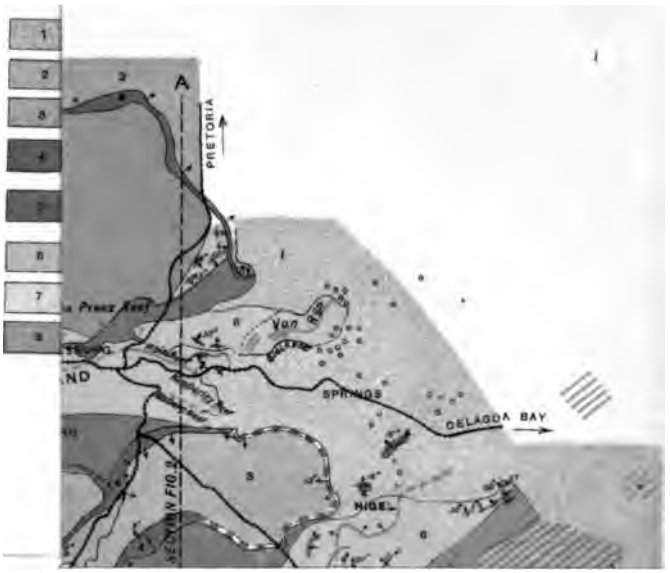
[illegible]DES IN THICK COAL-SEAM.

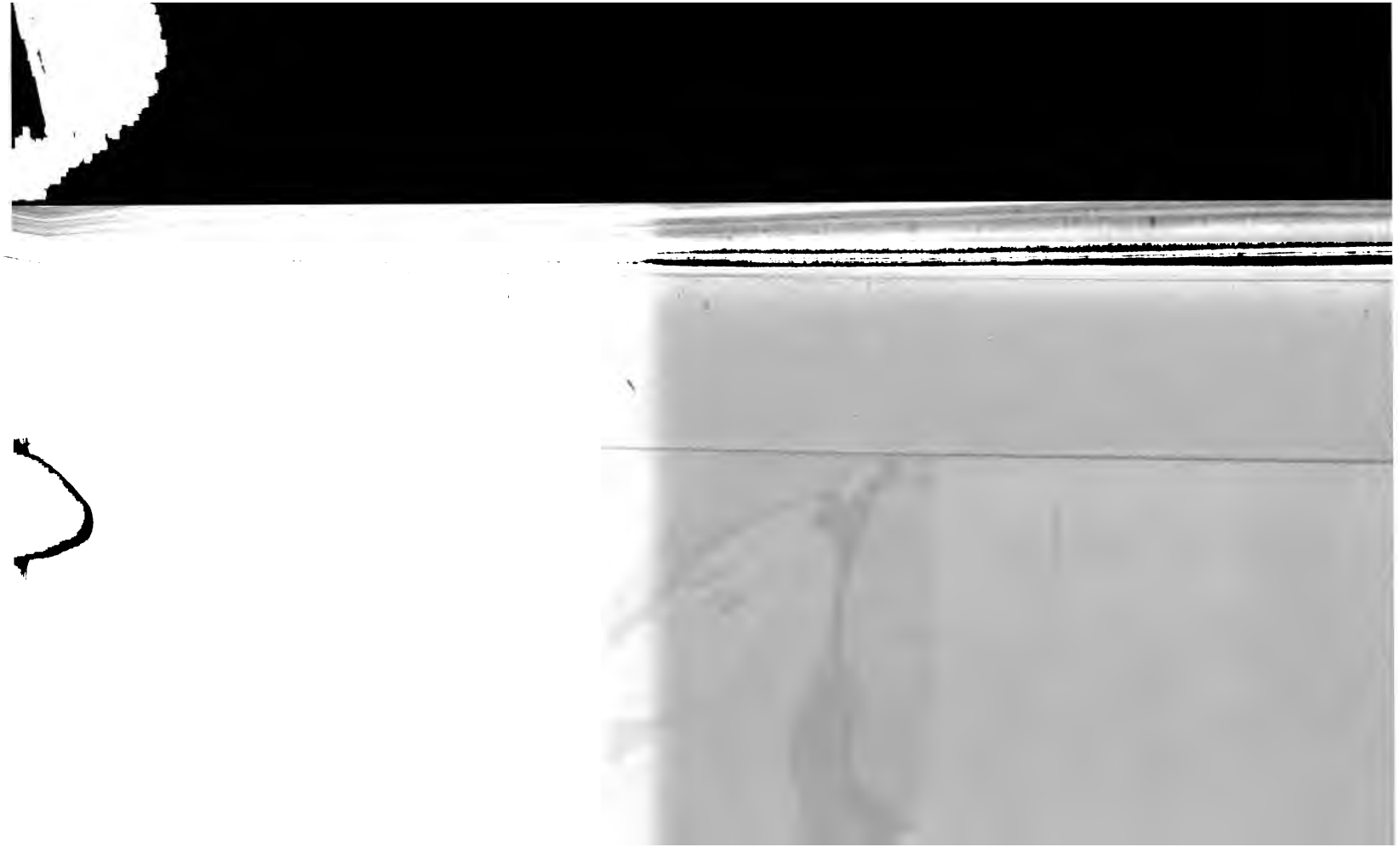


on Lyne.



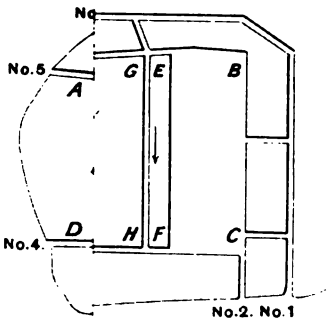
…AND ORANGE RIVER COLONY.





Limpopo River
PIETERSBURG
LEYDSDORP
Olifants River
LYDENBURG
BUSHVELD
MIDDELBURG
MACHADODORP
PRETORIA
BARBERTON
Komati River
LOURENÇO MARQUES
PORTUGUESE EAST AFRICA
HEIDELBERG
VREDEFORT
Vaal River
AMATONGALAND
VRYHEID
ZULU-LAND
NATAL
PIETERMARITZBURG
PORT NATAL
PONDOLAND
PORT ST. JOHN
INDIAN OCEAN
Great Kei River
EAST LONDON
REFERENCES.
POST-KARROO AND KARROO DEPOSITS.
PRE-KARROO DEPOSITS.
GRANITE AND METAMORPHIC SCHISTS.
DIRECTION OF AXIS OF MAIN-FOLDS.

4.



t to 1 Inch.

FIG. 7.

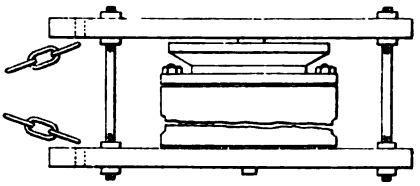
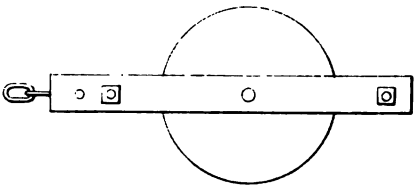


FIG. 8.



Scale, 20 Inches to 1 Inch.

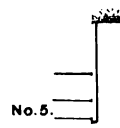
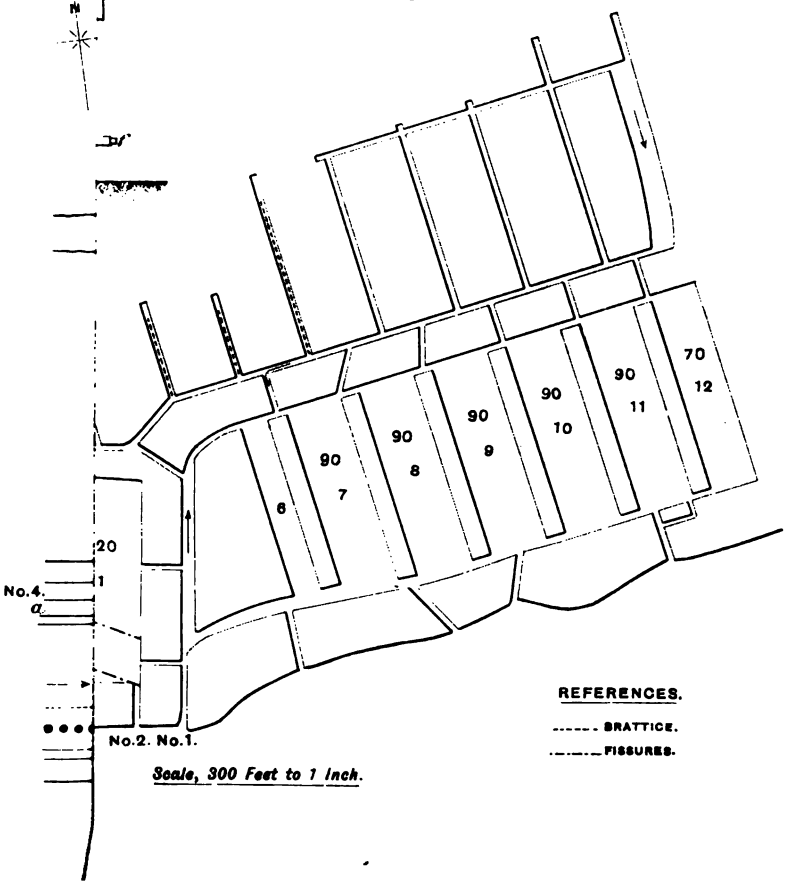


FIG. 5.



Scale, 300 Feet to 1 Inch.

[redacted]

Fig. 4.

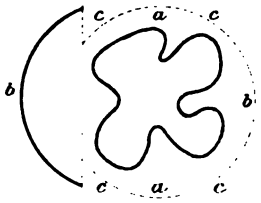


Fig. 5.

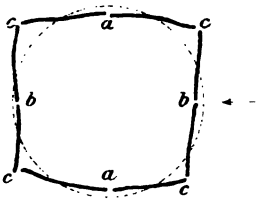


Fig. 8.

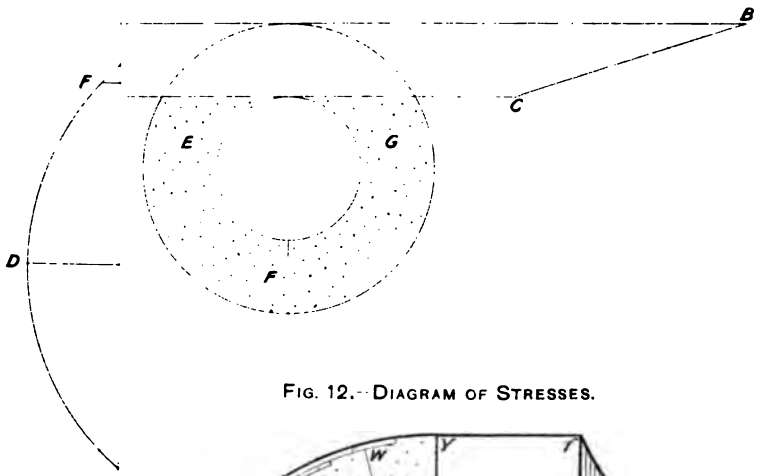
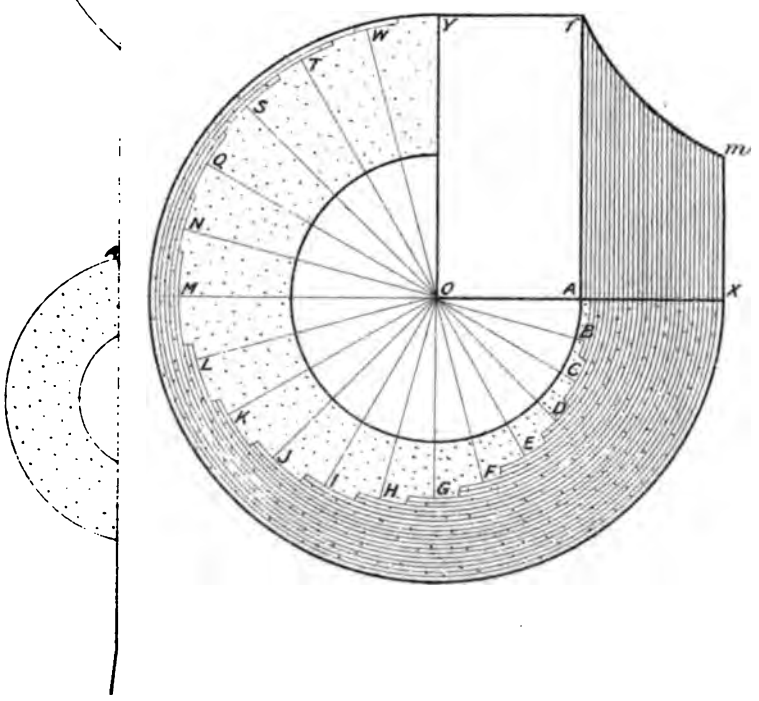
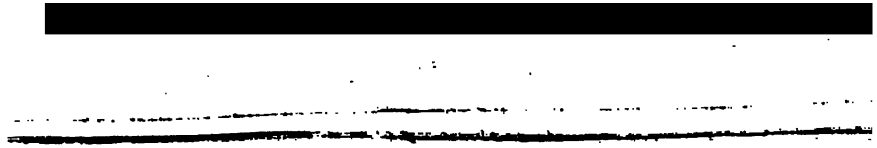


Fig. 12.—Diagram of Stresses.





...ern Railway Company."

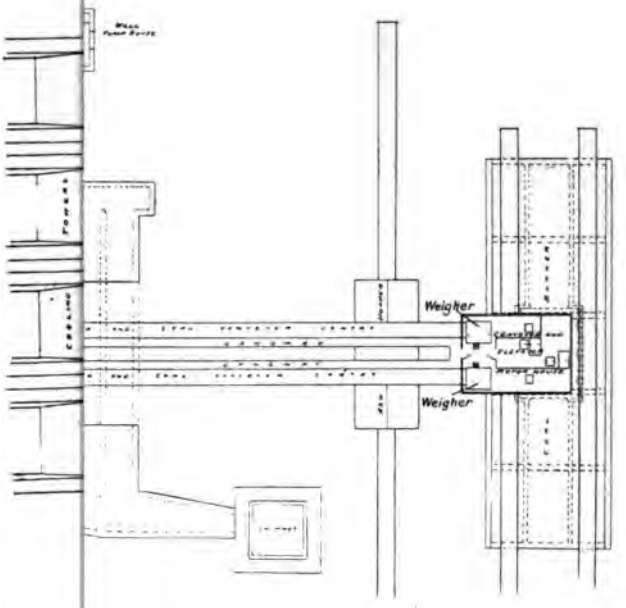
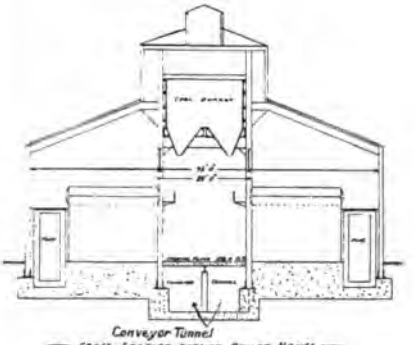
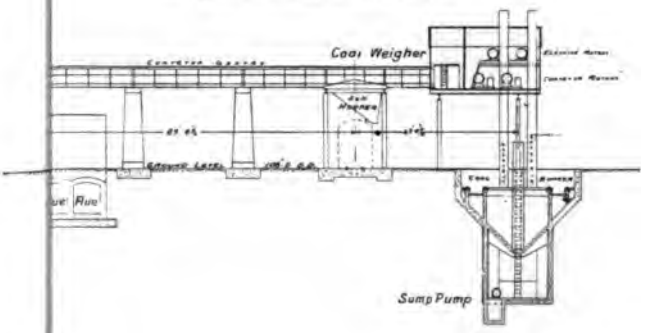


FIG. 4.





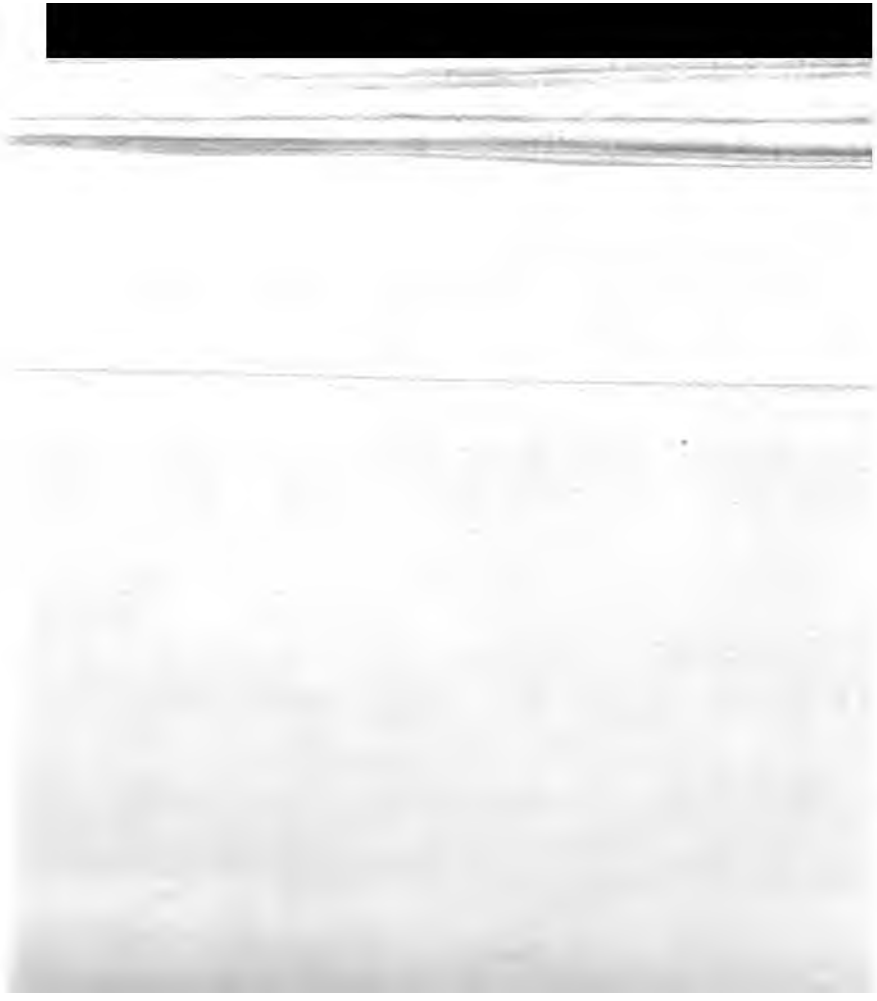
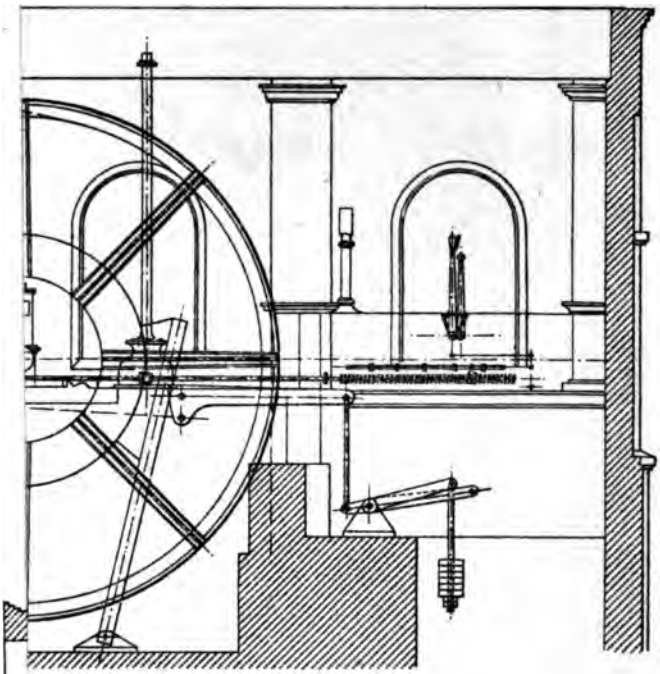


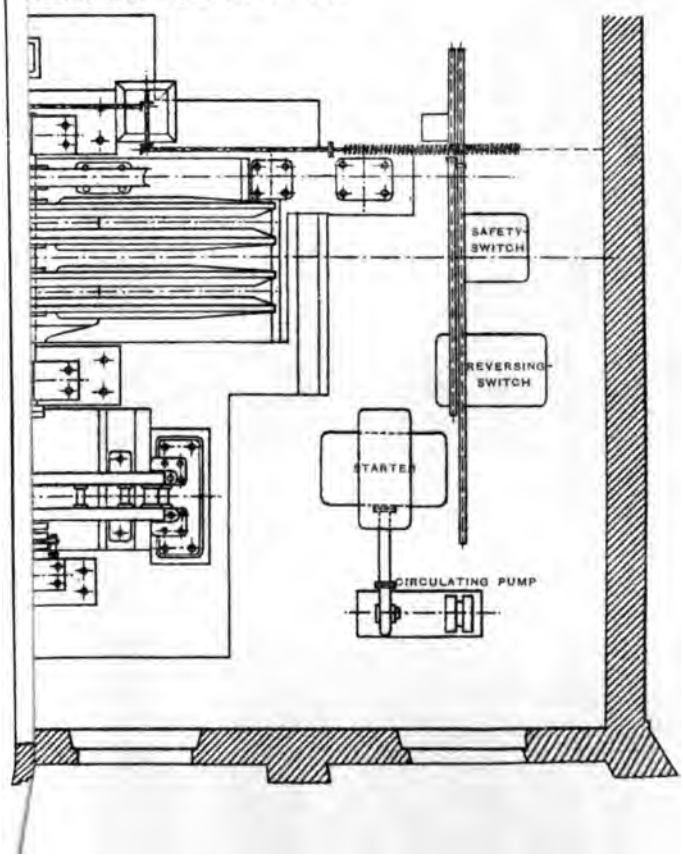
FIG. 7.—CENTRAL BAY OF ENGINE-HOUSE CONTAINING CONDENSING-PLANT.

Collieries of the Grand-Hornu, Belgium."

ICTRIC WINDING-ENGINE: ELEVATION.



ECTRIC WINDING-ENGINE: PLAN.



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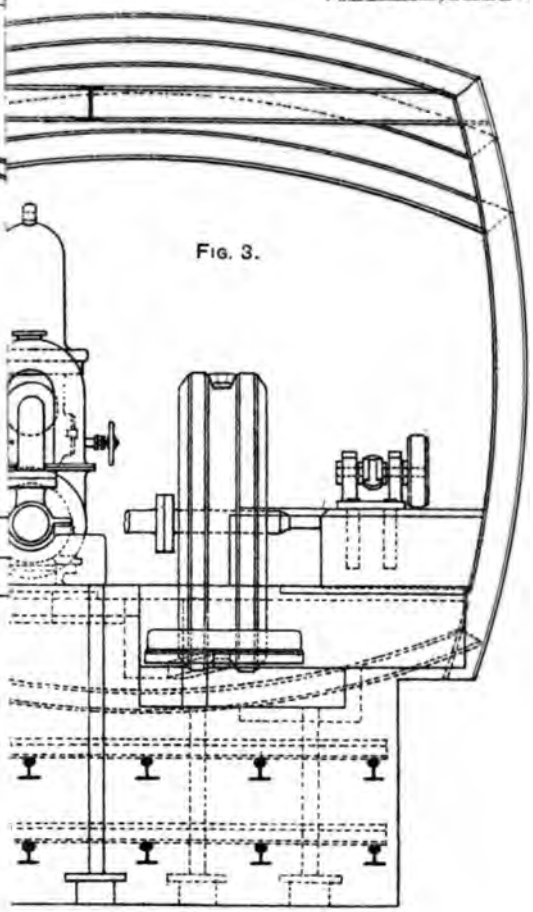


FIG. 3.

...NG-MAIN

SUMP

UNDERGROUND PUMP.

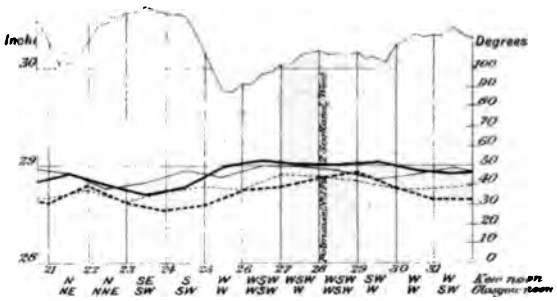
FIG. 1.—SIDE ELEVATION.
FIG. 2.—PLAN.
FIG. 3.—END ELEVATION.

[redacted]

NIMA TEMPERATURES, AND THE DIRECTION
OGETHER WITH THE EXPLOSIONS
LAND,

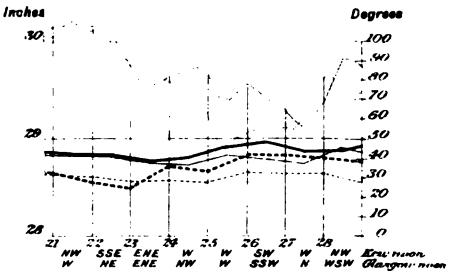
1906.

JANUARY.



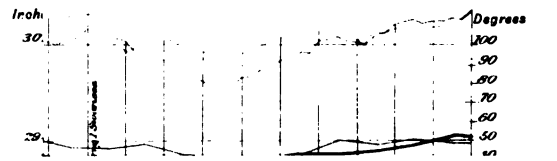
3 Deaths.

FEBRUARY.



No Deaths.

MARCH.

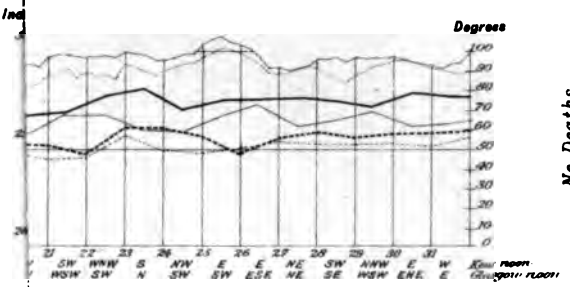


Death.

INIMA TEMPERATURES, AND THE DIRECTION
TOGETHER WITH THE EXPLOSIONS
TLAND.

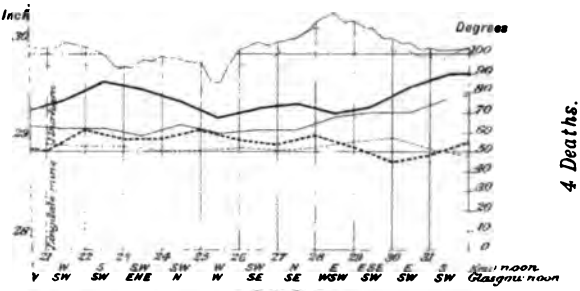
1906.

JULY.



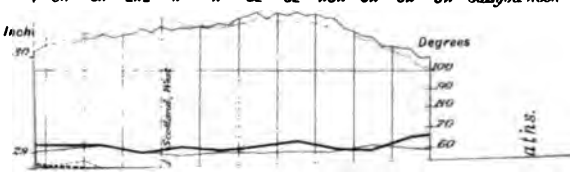
No Deaths.

AUGUST.



4 Deaths.

SEPTEMBER.



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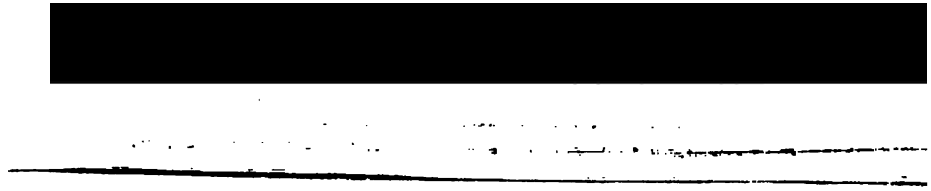

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